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SELECTED ABSTRACTS FOR INSTRUMENTATION AND AUTOMATION OF WASTEWATER FACILITIES

RAYTHEON COMPANY

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SELECTED ABSTRACTS
FOR
INSTRUMENTATION AND AUTOMATION OF WASTEWATER TREATMENT FACILITIES

by

A. E. Molvar

J. F. Roesler

Project No. 17110
Contract No. 68-03-0144
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Project Officer

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Cincinnati, Ohio 45268

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A collection of abstracts summarizing technical articles related to the instrumentation and automation of wastewater treatment plants was developed by the authors. This literature search encompassed most recognized environmental, instrument, and automatic control periodicals, symposium series, and conference proceedings published from 1967 to 1973. In addition, scientific and engineering abstracting publications were researched for pertinent literature.

Approximately 600 abstracts collected during this investigation are classified according to the following four categories: Instruments, Control Experiences and Strategies, Costs, and Support Material. These categories are further refined into numerous subcategories. For the reader's convenience, the abstracts are grouped according to the subcategories. Each entry contains a title, author, bibliographic citation, abstract, and keywords, respectively. An author index and source list are also included.

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ABSTRACT

A collection of abstracts summarizing technical articles related to the instrumentation and automation of wastewater treatment plants was developed by the authors. This literature search encompassed most recognized environmental, instrument, and automatic control periodicals, symposium series, and conference proceedings published from 1967 to 1973. In addition, scientific and engineering abstracting publications were researched for pertinent literature.

Approximately 600 abstracts collected during this investigation are classified according to the following four categories: Instruments, Control Experiences and Strategies, Costs, and Support Material. These categories are further refined into numerous subcategories. For the reader's convenience, the abstracts are grouped according to the subcategories. Each entry contains a title, author, bibliographic citation, abstract, and keywords, respectively. An author index and source list are also included.

This work was performed as part of a United States Environmental Protection Agency-funded study on the "State of the Art on Instrumentation and Automation of Wastewater Treatment Facilities." The selected abstracts were submitted in partial fulfillment of Contract No. 68-03-0144 between the United States Environmental Protection Agency and Raytheon's Environmental Systems Center.

Keywords: instrumentation, automation, control devices, wastewater treatment, storm water, analytical sensors, flow rate measurement, reliability, accuracy, costs, economics, control strategies, secondary treatment, advanced wastewater treatment, sanitary engineering, unit operations, and unit processes.

PREFACE

In June 1972 the United States Environmental Protection Agency (U.S. EPA) sponsored a contract with Raytheon Company (68-03-0144) entitled "State-of-the-Art Report on Instrumentation and Automation of Wastewater Treatment." The EPA had been active in this area prior to sponsoring the contract and had begun work on a literature search. During the course of the contract, both Raytheon Company and the U.S. EPA exchanged information that resulted in this collection of abstracts.

This collection of abstracts summarizes technical articles relating to the instrumentation of wastewater treatment systems. The literature search encompassed most recognized environmental and instrument periodicals, symposium series, and conference proceedings published from 1967 to 1973. In addition, scientific and engineering abstracting publications were researched for pertinent literature.

The abstracts are arranged by subject matter. Four main categories were chosen:

- I Analytical and Physical Measurements
- II Control Experiences and Strategies
- III Costs
- IV Support Material.

These four categories are further subdivided as delineated in the Table of Contents. Some articles, because of their nature, appear in more than one category for the convenience of the reader. Author and source indices are also provided at the end of the abstracts.

ANALYTICAL AND PHYSICAL MEASUREMENTS

Efficient wastewater collection and treatment require quantity and quality measurements. As the demand for improved wastewater treatment intensifies, the quantity of necessary chemical and physical analyses will also increase. This will result in a growth of laboratory personnel or increased usage of reliable automatic instruments. Because of the successful application of instruments in the chemical industry, instrumentation has the potential of generating reliable and rapid information essential for the rational operation of wastewater treatment processes. With modern instruments, the age-old requirement of real-time environmental data may become a reality.

Reliable sensors are a necessity for routine monitoring and automatic control of wastewater systems. Such sensors would provide rapid information on the influent and effluent streams as well as data on the condition and effectiveness of the treatment processes. Analog or digital controllers receiving this information would compare it to predetermined criteria, and institute suitable corrective actions to maintain a quality effluent.

Although the theory and laboratory application of analytical sensors are generally well established, there are many problems yet to be solved before such devices can be installed in the hostile environment of wastewater treatment plants, with the expectation of continued reliability with little or no maintenance. It is anticipated that this literature search will serve as the basis of information for future researchers in the development of rapid, reliable, on-line sensors and control strategies for wastewater treatment systems.

The following criteria directed the selection of technical articles during the instrumentation phase of the literature search:

- Research articles that demonstrated the applicability of various real-time analytical techniques and associated equipments
- Case studies and field evaluations of instruments in pertinent situations
- Follow-up articles that reduced instrument theory to practice
- Instrumentation review articles.

For accessibility, the instrument abstracts are grouped according to subcategories, as delineated in the Table of Contents.

MEASUREMENT AND SIGNIFICANCE OF ADENOSINE TRIPHOSPHATE IN ACTIVATED SLUDGE

Florida University, Gainesville, Dept. of Environmental Engineering
J.W. Patterson, P.L. Brezonik, and H.D. Putnam
Environmental Science and Technology, Vol. 4, No. 7, pages 569–575 (July 1970)

A method of adenosine triphosphate (ATP) measurement in activated sludge has been developed from the firefly reaction of luciferin and luciferase with ATP, in which light production is proportional to the ATP present. The purpose of the measurements was to utilize this parameter as a measure of metabolic activity and/or biomass. The ATP was extracted from the sludge by diluting it with 40 ml of boiling tris buffer and boiling it in a water bath for 10 minutes, with occasional shaking. The ATP extracted was mixed with firefly tail extract, and the light emitted was measured by liquid scintillation spectrometer. A number of tests were conducted to determine the effect of temperature of the ATP extraction, age and concentration of the reconstituted firefly lantern extract, and the presence of enzymatic inhibitors in the extracted samples. The technique has proved to be sensitive and reliable for quantitative determination of cellular ATP pool. The ATP levels in activated sludge are relatively constant under endogenous conditions, indicating the potential of ATP as an estimate of viable biomass, and respond rapidly to induced changes in metabolic activity. The advantages of an activity parameter over historically used biomass parameters for activated sludge operation control are manifold; the ATP assay holds promise as a sensitive tool for future research on sludge activity in process control.

Keywords: activated sludge, biomass, metabolism, inhibitors, separation techniques, spectrometers, toxicity, heavy metals, hydrogen ion concentration, enzymes, adenosine triphosphate, luciferin, luciferase, mercury, and enzymatic inhibitors.

RAPID DETECTION OF MICROORGANISMS IN AEROSPACE WATER SYSTEMS

Aerospace Medical Research Labs., Wright-Patterson AFB, Ohio
G.V. Levin, E. Usdin, and A.R. Slonim
Aerospace Medicine, Vol. 39, pages 14–16 (Jan. 1968)

Microbial contamination of water supplies, especially those in manned spacecraft, may be quickly detected by using the firefly bioluminescense assay for adenosine triphosphate (ATP). The method involves extracting the microbial ATP from the water sample, inserting the extractant and reaction mixture in a light-sensing instrument, injecting the sample into the reaction mixture, and measuring the peak light intensity, which is proportional to the quantity of ATP present. It is possible to detect as little as 0.0000007 micrograms of ATP, which is equivalent to about 100 cells of E. coli or one tetrahymena cell. Experiments were conducted with several bacteria, an algae, a fungus, and a protozoa to establish the equivalence between the amount of ATP and the cell count.

Keywords: bioluminescence, water pollution, potable water, assay, E. coli, chlorella, protozoa, fungi, cultures, clostridium, pseudomonas, streptococcus, adenosine triphosphate, corynebacterium striatum, bacillus subtilis, clostridium sporogenes, streptococcus salivarius, staphylococcus epidermidis, pseudomonas fluorescens, chlorella pyrenoidosa, saccharomyces cerevisiac, and tetrahymena pyriformis.

AUTOMATED COUNTING OF MICROBIAL COLONIES

Minnesota University, Minneapolis, Dept. of Chemical Engineering and Dept. of Microbiology
D.J. Schoon, J.F. Drake, A.G. Fredrickson, and H.M. Tsuchiya
Applied Microbiology, Vol. 20, No. 5, pages 815—820 (Nov. 1970)

The time required for direct counting of colonies on agar plates in order to estimate the population density of viable microorganisms has precluded studies requiring the measurement of such a parameter. Bowman, Blume, and Vurck have described a photoelectrical capillary tube scanner that automates the counting. The results obtained with an instrument similar to that of Bowman et al have been intensively analyzed with respect to precision and accuracy. The sources of "errors" have been ascertained, and the instrument's potentialities and limitations are discussed. Counts of almost 200,000 capilliary tube readings were made during the course of this study.

Keywords: E. coli, automation, instrumentation, lactobacillus, azotobacter, electronic equipment, cultures, counting, capillary tube scanner, Coulter counter, bacillus subtilis, and bacillus licheniformis.

METHOD FOR MEASURING AEROBIC DECOMPOSITION ACTIVITY OF ACTIVATED SLUDGE IN AN OPEN SYSTEM

Research Institute for Water Resources Development, Budapest (Hungary)
P. Farkas
Fourth International Conference on Water Pollution Research, Prague (Czechoslovakia)
(Sept. 1968) Preprint, Sec. II, Paper 1.9

The methods used to measure sludge activity are of great significance, since the activity indicates the concentration of living bacteria in the sludge and its physiological conditions. The best index for sludge activity would be the substrate removal rate itself, if it were possible to measure this in a direct and simple way. An activity measurement procedure was elaborated, relying upon the measurement of changes in the steady-state DO concentration of continuously aerated sludge samples. For decomposition activity measurement, only substrates supplying oxygen deficiency curves with a sharp breakdown at their total removal may be used, since only in the case of such substances can the decomposition time be determined exactly. The decomposition activity shows a linear proportionality to the bacterial concentration of the sludge. Acetate was added to sludge samples in concentrations ranging from 50 to 200 mg/l in order to obtain decomposition times ranging from 80 to 300 min; since acetate is in excess above a concentration of 50 to 100 mg/l, the measured activities depended mainly on the sludge concentrations. The activity vs substrate concentration functions were found to be different for the nontoxic acetate and the toxic compound (phenol). In the case of acetate that was above a concentration of about 100 mg/l, activity was nearly independent of the value of the acetate supply. With phenol, the activity vs substrate function showed a maximum value at 20 mg/l, higher concentrations exerting a toxic effect and thus reducing activity.

Keywords: activated sludge, kinetics, oxygen demand, aerobic treatment, measurement, respiration.

STATISTICAL EXPERIMENTAL DESIGN: BOD TESTS

Wisconsin University, Madison, Dept. of Civil Engineering
P.M. Berthouex and W.G. Hunter
Journal, Sanitary Engineering Division of American Society of Civil Engineers, Vol. 97, No. SA 4, pages 393—407 (August 1971)

Inefficient designs for wastewater treatment plants, resulting from ignorance of actual BOD conditions, have spurred the development of an experimental design technique. Although this technique was applicable to many different types and complexities of equations, the BOD equation was chosen for use as an example. A mathematical model was chosen: f (k, xi sub mu), in which xi sub mu are variables and k is the vector of parameters and assumed to be correct. It was further assumed that: 1) the purpose of the experiment was to select the settings for the variables in order to obtain the most precise estimates of k, and 2) the experimental variables can be accurately set and controlled. The use of matrix algebra allowed the designer to determine which of the ranges of values for the parameters was limiting. Knowledge of these ranges for the various variables allowed the experiment to be designed around the most important ranges, thereby reducing unnecessary work by obtaining only the precise information desired. The use of replicate operations was examined, as were the problems of lag reactions and nitrification. The procedure is readily extensible to more complex models, since it actually gains in accuracy as complexity increases.

Keywords: systems analysis, biochemical oxygen demand, kinetics, statistical methods, mathematical models, analytical techniques, design data, industrial wastes, municipal wastes, nitrification, water analysis, **Box-Lucas method.**

AN AUTOMATIC ELECTROLYTIC RESPIROMETER—ITS CONSTRUCTION AND USE

Water Pollution Research Lab., Stevenage (England)
H.A.C. Montgomery, A.B. Oaten, and D.K. Gardiner
Effluent and Water Treatment Journal, Vol. 11, No. 1, 9 pages (1971)

An automatic respirometer suitable for measuring oxygen consumption rates up to over 200 mg/l has been developed. The instrument consists of two parts: a constant-temperature water bath that holds up to six reaction flasks and a control console. The reaction flask is a five-neck quick demountable flask. The control console is programmed: 1) to interrogate the functioning of each reaction every minute, and 2) to record whether or not the cell is consuming oxygen (this is a function of whether or not the current is flowing in an electrolytic cell). The result is a series of times on the printout that can be associated with a known increment of oxygen. Procedures for operating the device are included. Sources of error (such as the failure to absorb carbon dioxide, changes in barometic pressure, and oxygen deficiency) as well as the means to circumvent these errors, are discussed. Sensitivity and performance data is also presented. Examples of the use of the instrument in treatability studies are described. The automatic respirometer developed at the WPRL is a valuable tool in determing the treatability of wastes.

Keywords: wastewater treatment, biochemical oxygen demand, chemical oxygen demand, measurement, oxygen demand, and oxygen consumption rates.

LABORATORY TESTS FOR PLANT OPERATION CONTROL AND STREAM QUALITY MEASUREMENT

Delaware University, Newark, Dept. of Civil Engineering
K. Banerji
Journal, Water Pollution Control Federation, Vol. 43, No. 3, pages 399—406 (1971)

A critical evaluation is made of the current analyses used to appraise wastewater and stream waters. The time-consuming 5-day BOD test is likely to be replaced by the rapid total organic carbon, COD, and TOD tests. For activated sludge, the MLVSS test appears to be better suited than the SS test. Determination of an active biomass by the organic N, DNA, or dehydrogenase methods is more complicated than MLVSS determinations. The SVI test is of questionable value because of its dependance on many uncontrollable variables. The ORP analysis provides erratic results due to unpredictable and complex reactions. An appraisal of stream water quality requires consideration of the mixing of the effluent discharge system, aside from the chemical and biological analyses.

Keywords: sewage treatment, water pollution control, laboratory tests, measurement, water analysis, biochemical oxygen demand, water quality, analysis, chemical oxygen demand, oxidation-reduction potential, analytical techniques, tests, sludge, sewage treatment plants, total organic carbon, total oxygen demand, suspended solids, mixed liquor suspended solids, sludge volume index.

AUTOMATIC RECORDING AND MEASURING INSTRUMENTS FOR THE DETERMINATION OF THE BIOCHEMICAL OXYGEN DEMAND IN SAMPLES OF WASTE WATER

H. Steinicke
Stuttg. Ber. Stedl. Wasserw., 158 pages (1968)

The author stresses the importance of careful and accurate sampling techniques to avoid inaccurate results in determining the BOD in wastewaters and sewage. Because existing methods have proved unreliable and unsuitable for determinations in series, the author has developed a method for determining the BOD in wastewaters and sewage. This method operates automatically and also records the results of measurements.

Keywords: biochemical oxygen demand, automatic measurement.

BOD VS COD VS TOC VS TOD

E. M. Davis
Water Wastes Eng., Vol. 8, No. 2, pages 32—34 and 38 (1971)

The author discusses and compares the advantages and disadvantages of the BOD, COD, total organic carbon (TOC), and total oxygen demand (TOD) tests for measuring pollution. Although the TOC and TOD tests are rapid, the initial cost of the required apparatus might be prohibitive for some laboratories, and it is concluded that the established tests for BOD and COD will continue to be used.

Keywords: total organic carbon, biochemical oxygen demand, chemical oxygen demand, total oxygen demand.

BIOCHEMICAL OXYGEN DEMAND

ANALYSIS OF LAG PHASE BOD CURVES USING THE MONOD EQUATIONS

H. B. Braun and P. M. Berthouex
Water Resources Research, Vol. 6, No. 3, pages 838—844 (June 1970)

The Monod bio-kinetic relations are used to develop a three-parameter model in order to describe the biochemical oxidation of wastewater substrates as observed in biochemical oxygen demand (BOD) tests, including those tests with an initial lag phase. A criterion relating the biological parameters of the model to the occurrence of a lag phase is presented. The model was applied to several sets of data that reflect a variety of conditions. Some statistical problems involving parameter correlation were noted.

Keywords: biochemical oxygen demand, mathematical models, mathematical studies, oxygen demand, oxygen sag, water quality, water pollution effects, biodegradation, nutrients, Monod equations, and reaction rates.

PHYSICAL AND BIOCHEMICAL ASPECTS OF BOD KINETICS

Technische Hochschule, Karlsruhe (West Germany) Lehrgebiet fur Ingieurbiologie
L. Hartmann and P. Wilderer
Water Research, Vol. 2, No. 1, pages 30—37 (Jan. 1968)

Two main theoretical concepts are generally accepted to describe the BOD process: 1) the biochemical concept considers that biochemical reactions within the cell are responsible for the reaction rates, and 2) the physical concept emphasizes convection and diffusion processes during the transport of organic pollutants to and through the living cell. A set of experiments used biochemical methods to evaluate and describe BOD kinetics. A constant substrate concentration was brought into contact with various amounts of activated sludge. It was impossible to use just one mathematical formula to describe the whole BOD process. Second order reactions were the best approximation to evaluate the process at low-load values. In this case, turbulence and other physical factors had a positive influence upon the process. Biochemical reactions were responsible for the rate of the BOD reaction only at high-load values.

Keywords: biochemical oxygen demand, biodegradation, water pollution effects, activated sludge, organic loading, physical properties, diffusion, pollutants, chemical reactions, turbulence, biochemical reaction kinetics, and reaction rates.

MATHEMATICAL MODELS FOR EXPRESSING THE BIOCHEMICAL OXYGEN DEMAND IN WATER QUALITY STUDIES

Iowa State University, Ames, Dept. of Civil Engineering and Engineering Research Institute
M. D. Dougal and E. R. Bauman
Proceedings, Third Annual American Water Resources Conference, San Francisco (Calif) pages 242—253 (Nov. 1967)

The development and application of the widely used monomolecular model for biochemical oxygen demand (BOD) are reviewed. Results of laboratory BOD studies are revealed to establish that the monomolecular model fails to satisfy its fundamental assumptions. Temporal variations in the rate constant and the ultimate BOD value are explored for three types of wastes: 1) raw domestic sewage, 2) final effluents from various waste treatment processes, and 3) contents of an agricultural waste lagoon. Two different mathematical models for BOD, which statistically are superior to the monomolecular model, are presented. These models may be useful in future studies of stream water quality and in the determination of stream assimilative capacities.

Keywords: biochemical, oxygen demand, mathematical models, statistical models, statistical methods, oxidation, oxygen demand, dissolved oxygen, water pollution effects, computer programs, forecasting, BOD models, and monomolecular BOD models.

A SECOND-ORDER EQUATION, NOT BASED ON ULTIMATE OXYGEN DEMAND, DESCRIBING THE FIRST PHASE OF OXYGEN UPTAKE IN BIOCHEMICAL OXYGEN DEMAND REACTIONS

Newcastle-upon-Tyne University (England)
J. R. Simpson
Water Pollution Control, Vol. 67, No. 4, pages 433—453 (1968)

The use of respirometer systems for the determination of oxygen-demand values of wastewaters and aerobic biological systems are discussed in detail. The respirometer described has good sensitivity and great ease for withdrawing samples for analysis during a run. The reproducibility of results from settled sewage is excellent, with a maximum difference of 1.11% from the mean at 120 hours. A second order equation that is not based on ultimate oxygen demand and describes the first phase of oxygen uptake in biochemical oxygen demand reactions is proposed. The proposed formula, which relates the rate of reaction to the substrate concentration and to the population of organisms, gives an excellent fit to the data observed for the first part of the reaction. The significant feature of the formula is that the ultimate oxygen demand is not required, but the removable oxygen demand must be determined. In the given formula, the value of a conversion constant is a function of the substrate and the organisms effecting treatment. When the values of the constants and the overall rate of metabolic processes have been determined for various systems, both the critical oxygen uptake value and the time when it occurs can be calculated from a minimum of data, obtained from the beginning of an experiment.

Keywords: biochemical oxygen demand, bioassay, biological treatment, respiration, equilibrium, microorganisms, metabolism, oxygen uptake, oxidation/synthesis, respirometer, confined growth, normal growth, and suspended solids.

RESPIROMETRIC DETERMINATION OF BOD

Government Industrial Development Lab., Sapporo (Japan)
T. Nakata and Y. Kumagai
Fifth International Water Pollution Research Conference, San Francisco, Preprint, Paper I-22, 8 pages (July 26—August 1, 1970)

The construction and efficiency of a respirometer and the results of some experiments concerning the microorganisms are presented. The apparatus consists of a reaction chamber as master controller, a measuring unit, and a recorder. The reaction chamber includes: 1) a culture flask with a magnetic stirrer inside and a small vessel for carbon dioxide, 2) an absorbant, 3) a manometer for sending a pressure signal to a relay circuit, and 4) an electrolytic oxygen generator with a copper sulphate electrolyte. When dissolved oxygen in a sample is consumed by microorganisms, the same amount of carbon dioxide as that of the oxygen consumed is evolved by the respiratory action of the microorganism. The absorption of the carbon dioxide by the absorbant causes a decrease of pressure in the closed reaction system and the level change of dilute sulphuric acid in the manometer closes the relay circuit. The oxygen generator produces oxygen, which is fed to the reaction system at a constant rate until the initial pressure is restored. Hence, the amount of consumed oxygen is proportional to the integral electrolysis time. This method is known to be convenient to speedy measurements. By using glucose, the BOD can be determined within from 10 to 15 hours at 20 degrees C. If the measurement is taken at a higher temperature, the result can be obtained in a few hours.

Keywords: biochemical oxygen demand, respiration, instrumentation, oxygen demand, aerobic bacteria, measurements, microorganisms, and mathematical models.

SHORT-TERM BOD USING THE AUTOMATIC RESPIROMETER

Rose Polytechnic Institute, Terre Haute, Indiana
R. M. Arthur and W. N. Hursta
Proceedings of the Industrial Waste Conference (23rd), pages 242—250 (1968)

Short-term oxygen uptake rates, using an automatic respirometer and 5-day BOD values, were determined on duplicate samples of settled sewage. The amount of oxygen uptake after 4- and 7-hour periods was plotted against the 5-day BOD value and lines of best fit determined. The average deviation of 5-day BOD from these lines was 21.3% (utilizing 4-hour uptake) and 15.8% (utilizing 7-hour uptake). These deviations are comparable to the reported accuracy of ±20% for the 5-day BOD test. The oxygen uptake curves obtained were investigated, and an equation of the form Y = A + BX + C(X SQ) was found to best relate oxygen uptake to time. Attempts to correlate the coefficients C or B for a particular sample with the 5-day BOD resulted in average deviations of 5-day BOD from the line of best fit of 23.8% for the coefficient C and 22.0% for the coefficient B.

Keywords: biochemical oxygen demand, sewage, least squares method, instrumentation, water, oxygen uptake, and automatic respirometer.

DEVELOPMENT AND USE OF A LARGE-VOLUME AUTOMATIC RESPIROMETER

Newcastle-Upon-Tyne University (England)
J. R. Simpson and G. R. Nellist
Water Pollution Control, Vol. 69, No. 5, pages 596—605 (1970)

An automatic recording respirometer was assembled from parts readily available in most laboratories for measuring the oxygen utilization of various wastes. A photoelectric cell unit was employed to control the oxygen supply, and carbon dioxide was removed by absorption in

a sodium hydroxide solution. The entire apparatus was kept at constant temperature by a water bath. Oxygen was introduced in small increments, and CO2 was removed as instantaneously as possible in order to keep the pressure and composition of the atmosphere above the respiration flask as nearly constant as possible. Correlation between oxygen utilization (OU) measurements and BOD measurements was excellent, with the OU results being at least as reproducible as the BOD measurements. The major importance of the respirometric method is its ability to supply information on the oxygen requirement, retention time, and reaction rate of wastes for which facilities are being designed in a matter of hours instead of weeks.

Keywords: analytical techniques, biochemical oxygen demand, respiration, sampling, automatic control, pressure, temperature, oxygen absorption, carbon dioxide, metabolism, toxicity, time lag, design criteria, water analysis, wastewater treatment, oxygen utilization, and buffers.

AUTOMATIC RECORDING RESPIROMETER

Interstate Sanitation Commission, New York, N.Y.
A.I. Mytelka and W.E. Brenner
Water Qual. Instrum., 1, pages 142—151 (1972)

A recording respirometer is described. The results obtained with the instrument and with a Warburg respirometer are the same in each case. However, the advantages in using the new recording respirometer are: 1) the labor necessary to set up and carry out the tests, as well as that required for data reduction, is greatly reduced, 2) the unit can run evenings, weekends, and holidays unattended, 3) a printed record is provided, 4) the instrument is insensitive to barometeric fluctuations, 5) the unit can operate at high sample concentrations, eliminating the need for dilution, and 6) large samples can be accommodated, thus reducing the magnitude of errors inherent in testing small samples.

Keywords: respirometer, automatic measurement, and organics.

DETERMINING CHLORINE DIOXIDE AND CHLORITE

Newcastle and Gateshead Water Co., Newcastle-upon-Tyne (England)
A. T. Palin
Journal of the American Water Works Association, Vol. 62, No. 6, pages 483 and 484 (June 1970)

Chlorine dioxide is being increasingly used as a water disinfectant. Residual chlorine dioxide may, however, be accompanied by traces of chlorite, which carries a possible health hazard. In determining chlorine dioxide in water by the DPD method, residuals previously regarded as chlorine dioxide could be due to chlorite. A modification to the DPD method, which meets the requirement to accurately determine the concentrations of the several chlorine compounds in water as the result of chlorine dioxide addition, was made previously. A detailed discussion of the modified DPD method is presented. The required reagents and procedures for preparing these reagents are presented. The laboratory procedures for measuring chlorine dioxide, free chlorine and chlorine dioxide, monochloramine, dichloramine, and total available chlorine (including chlorite), are given. The calculations to determine concentrations of each compound are shown.

Keywords: water purification, laboratory tests, analytical techniques, public health, hazard, disinfection, chlorination, water treatment, chlorine dioxide, reagents, and chlorite.

WASTEWATER RESIDUAL CHLORINE ANALYZER

W. C. Conckling and H. R. Holland
Water Wastes Engineering, Vol. 3, No. 6, pages 45—47 (1966)

An illustrated description is given of an instrument developed for continuous amperometric determination of residual chlorine in primary sewage effluents. Arrangements for sampling without altering the residual chlorine level and for the problem of grease fouling are discussed, together with the technique for automatic control of chlorination by feedback on flow and residual chlorine.

Keywords: chlorination, disinfection, residual chlorine, feedback control, and grease fouling.

SELECTION OF A METHOD TO DETERMINE RESIDUAL CHLORINE IN SEWAGE EFFLUENTS

Illinois State Water Survey, Peoria, Water Quality Section
S. Lin, D. L. Hullinger, and R. L. Evans
Water and Sewage Works, Vol. 118, No. 11, pages 360--364 (November 1971)

Residual chlorine in the effluents of three sewage works that serve Peoria, Morton, and Washington, Illinois, and in chlorine-demand-free water was determined by four methods: MSI (modified starch-iodide "forward" titration), SIB (starch-iodide backward titration), DPD (N, N-diethyl-p-phenylene diamine), and LCV (leuco crystal violet). The purpose of this investigation was to determine which of the four methods would be most appropriate for determining residual chlorine in sewage effluents. Testing procedures basically involved dosing a sample to a calculated quantity of chlorine using stock solutions for varying contact periods and measuring the chlorine residual with different methods. A statistical analysis of all observed data was made, using the t-test of pairing observations. The MSI method was chosen for the continuation of the sewage chlorination study because of its simplicity, speed, and economy over the standard SIB titration method and its dependability over the DPD and LCV methods. The DPD and LCV methods, although excellent for testing water, were found inapplicable in the determination of residual chlorine in sewage effluents at the concentrations used in the testing procedures. With some modification they might be satisfactory for use with chlorinated sewage samples, especially the LCV method. All comparative data for the methods analyzed and the chemical characteristics of treated sewage effluents are presented in tabular form.

Keywords: analytical techniques, sewage effluents, water analysis, chlorine, halogens, statistical methods, chemical analysis, volumetric analysis, waste identification, pollutant identification, starch-iodide titration, N, N-diethyl-p-phenylene diamine, leuco crystal violet, and chlorine residual.

CHLORINE RESIDUAL ANALYZER/MONITOR CHALLENGES NEED FOR SIMPLICITY, ACCURACY, RELIABILITY

N. K. Stenberg
Water and Wastes Engineering, New York, 7(12): pages 41 and 42 (Dec. 1970)

An amperometric-type chlorine residual analyzer developed by Capital Controls Co. is described. Simplicity, accuracy, and reliability shown in field tests lead to claims that electrode cleaning, frequent recalibration, and zero adjustment problems are eliminated.

Keywords: water analysis, wastewater, chlorine, instruments, and chlorine residual analyzer/monitor.

ADVANCED INSTRUMENTATION FOR DISSOLVED OXYGEN MEASUREMENTS

University of Michigan, School of Public Health, Environmental Chemistry Department, Ann Arbor
K.H. Mancy

Analysis Instrumentation, Vol. 8; Instrument Society of America Symposium, 16th Annual Proceedings, held in Pittsburgh, Pa. (May 25—27, 1970); Instrument Society of America, Pittsburgh, Pa., pages V2/1 (1970)

Among the various methods of analysis for dissolved oxygen in natural and wastewaters, the Winkler titrimetric procedure and the voltametric membrane electrode systems are most widely used. Discrepancies between these methods of analysis are based on the fact that the former is strictly an extensive-type measurement while the latter is an intensive-type measurement. The Winkler test essentially measures the number of oxygen molecules in a given sample volume based on stoichiometric calculations, while the membrane electrode strictly measures the activity of molecular oxygen. This difference is particularly significant in the presence of "salting in" and "salting out" impurities. The relative merits of each type of measurement and their applications to natural and wastewater systems are discussed. Performance characteristics of steady-state and transient voltametric membrane electrode measurements are presented with illustrative examples of field application.

Keywords: instruments, dissolved oxygen, water analysis, wastewater, sampling techniques, measurement methods, and water-quality standards.

POLAROGRAPHIC OXYGEN ANALYZER RESPONSE: THE EFFECT OF INSTRUMENT LAG IN THE NON-STEADY STATE REAERATION TEST

Washington University, Seattle, Department of Chemical Engineering
A.A. Benedek and W.J. Heideger

Water Research, Vol. 4, pages 627—640 (Sept. 1970)

The response characteristics of a polarographic oxygen analyzer are determined both theoretically and experimentally. A simplified diffusion theory adequately describes the response of the polarographic probe to a step change as well as to an exponential change. Minor disagreements are believed to have been due to sideways diffusion, membrane laxity, and anode contamination. The polarographic probe used in this study was capable of a response in the unsteady-state aeration test that was repeatable to within 2 percent or better. Slow instrument response can cause unsteady-state aeration test results to appear low. This error increases with both the aeration rate and the probe membrane thickness. It is shown that substantial errors could be introduced by the use of such an analyzer, and a test procedure is suggested to evaluate their significance.

Keywords: polarographic analysis, reaeration, test procedures, oxygen, aeration, electrochemistry, electrodes, and bio-oxidation.

THE APPLICATIONS OF A MODIFIED GALVANIC-CELL OXYGEN ELECTRODE IN EFFLUENT TREATMENT STUDIES

C. F. Forster and J. S. G. Brookman
Water Waste Treatment, 14, No. 2, pages 11—14 (1971)

A galvanic-cell electrode for the measurement of oxygen concentration was used for the continuous determination of BOD in an activated-sludge pilot plant. There was no deterioration in electrode performance over a period of 5 months, and oxygen concentrations recorded were comparable with results from the Winkler method. Monitoring of BOD will enable the efficient control of aeration to give optimal oxygen levels.

Keywords: dissolved oxygen, galvanic cell, wastewater, and BOD.

THE CONTINUOUS MEASUREMENT AND RECORDING OF OXYGEN CONSUMPTION AS A MEANS OF CONTROLLING SEWAGE WORKS AND WATERS

H. Thiele and K. H. Schmidt
Ost. Abwass. Radsch., 14, pages 83—85 (in German) (1969)

A newly developed instrument is described for continuous measurements of oxygen consumption in polluted waters, which can record the lowest as well as the highest oxygen deficit. This instrument can also be used to determine the degradability of wastewaters, measure the oxygen content per surface unit of waters, and control influents and effluents of sewage treatment plants.

THE DESIGN, CONSTRUCTION, AND CHARACTERISTICS OF A NEW LONG-LIVED STEAM-STERILIZABLE OXYGEN ELECTRODE

J. S. G. Brookman
Biotechnol. Bioengng, 11, pages 323—335 (1969)

An electrode for the measurement of oxygen concentration, which can be sterilized with steam, is described. The casing, formed from a nylon rod, contains a silver cathode, a lead anode, and potassium orthophosphate as the electrolyte, and a membrane of fluorinated ethylene-propylene copolymer film is used. The response is linear for partial pressures of oxygen over the range of 0.015—1000 mm mercury, and the 90 percent response time is 15 sec, using a 0.001-inch thick membrane.

Keywords: oxygen electrode, sterile construction, and design.

COMPARISON STUDIES OF WINKLER VS. OXYGEN SENSOR

Decatur Sanitary District, Ill.
J. F. Reynolds
Journal Water Pollution Control Federation, Vol. 41, No. 12, pages 2002—2009 (Dec. 1969)

The determinations of dissolved oxygen levels in wastewater treatment and effluent disposal are of great use in a number of ways. In-plant laboratory studies of the use of a polarographic oxygen sensor in comparison with the more common Winkler method were conducted. The advantages found were: 1) the preparation and standardization of a reagent solution are eliminated, 2) the time spent in analysis is reduced, 3) the method is less tedious, and 4) the correlation with the Winkler method is excellent. Both laboratory experiences and data support these conclusions.

Keywords: dissolved oxygen, water analysis, laboratory tests, water quality, instrumentation, monitoring, sewage treatment, waste treatment, and dissolved oxygen sensor.

SPECTROPHOTOMETRIC DETERMINATION OF DISSOLVED OXYGEN IN WATER

C.S. Sastry, R.E. Hamm, and K.H. Pool
Analytical Chemistry, 41, pages 857—858 (1969)

A spectrophotometric method of determining dissolved oxygen is described. Manganese chloride and sodium hydroxide solutions are added to the sample, which is then reacted with cyanogen diaminocyclohexane-tetra-acetic acid, and after adding sulphuric acid the absorbance of the purple complex with manganese is measured at 500 mμ. Using a modified Winkler method to measure the oxygen concentration in duplicate samples, a calibration curve was constructed showing a linear relation with absorbance up to 11 ppm oxygen. The interference effects of copper, iron, and calcium in each method are tabulated.

Keywords: dissolved oxygen, spectrophotometric, and Winkler.

APPLICATION OF ATOMIC ABSORPTION SPECTROSCOPY FOR MONITORING SELECTED METALS IN AN INDUSTRIAL WASTE

A.M. Tenny and G.H. Stanley
Proceedings, 22nd Industrial Waste Conference, Purdue University
Engng Extn Ser·No. 129, pages 455—467 (1967)

The authors describe the use of atomic absorption spectroscopy for determining low concentrations of metals in trade wastewaters and sewage works effluent at Chicago. Tabulated results are given showing the range of concentrations of several metals that can be expected in different types of wastewater.

Keywords: atomic absorption, heavy metals, and trade wastes.

DETERMINATION OF CHROMIUM IN WATER BY ATOMIC ABSORPTION SPECTROPHOTOMETRY: APPLICATION TO THE MEASUREMENT OF RATE OF FLOW IN WATER COURSES

F.P. Burelli and F. Ecrement
Chem. Analyt., 51, pages 561—566 (in French), (1969); Analyt Abstr., 19, Abstr. No. 5262 (1970)

After extraction from water by isobutyl methyl ketone in the presence of hydrochloric acid, very low concentrations of chromium are determined by measuring the absorption at 357-87 nm, using an air-acetylene flame and 5-cm laminar burner. For concentrations of 0.2 μg chromium per ml, the coefficient of variance obtained in eight determinations was 2.7 percent. Comparison with results obtained by the diphenylcarbazide method with spectrophotometric determination at 540 mu showed good agreement. The method has been applied to the determination of dichromate tracer used in stream flow measurements.

Keywords: spectrophotometric, chromium, and flow rate.

POLAROGRAPHIC DETERMINATION OF ALUMINUM IN EFFLUENTS

M.M. Buzlanova and N.A. Kurochkina
Zav. Lab., 31, 947 (1965); Analyt. Abstr., 13, Abstr. No. 7162 (1966)

Aluminum in wastewaters in concentrations down to 0.01 mg per ml has been determined polarographically. After the separation of the aqueous layer from the hydrocarbon layer, the adjustment of pH value to 11, and the removal of precipitated ferric hydroxide by filtration, the filtrate is mixed with a solution of acetic acid and sodium acetate containing 1 percent of acid chrome blue K, and a differential polarogram is recorded. The half-wave potential and peak heights are not affected by variations in the composition of the basal electrolyte.

Keywords: polarograph and aluminum.

METALS KEPT IN CHECK

Perkin-Elmer Corp., Spectroscopy Department, Norwalk, Conn.
H.L. Kahn
Water and Wastes Engineering, New York, 8(10): 37 (Oct. 1971)

Investment by the Charlotte, North Carolina, Water Department in an atomic absorption spectrophotometer has led to the establishment of a monitoring program designed to keep track of concentrations of metals in the Charlotte treatment plants as well as in local industrial wastes. Sewage is monitored daily to ensure that industrial wastes do not exceed the limit on metallic content.

Keywords: water quality control, sampling techniques, spectrophotometry and metal concentration monitoring.

AN AUTOMATED METHOD FOR DETERMINING MERCURY IN WATER

Depart of Energy, Mines and Resources, Ottawa (Ontario), Inland Waters Branch
P.D. Goulden and B.K. Afghan
Canada Department Energy, Mines and Resources, Inland Waters Branch Technical Bulletin No. 27, (1970)

A method is given for determining the mercury content in water with mercury concentrations as low as 0.05 micrograms/liter. The method was applied to water samples containing both inorganic- and organo-mercury compounds. It involves the oxidation of organo-mercury compounds by ultraviolet irradiation, followed by the reduction of the mercury to the elemental state. The mercury is swept out of the solution by a stream of air and its concentration measured in an absorption cell in an atomic absorption spectrophotometer. For levels of mercury in the range 1.0 to 32 micrograms/liter, the method is automated to measure 20 samples per hour. For levels of mercury in the range 0.05 to 1.0 micrograms/liter, only 10 samples per hour can be processed because a longer sampling time is required.

Keywords: pollutant identification, water analysis, heavy metals, spectrophotometry, flame photometry, analytical techniques, poisons sampling, automation, instrumentation, measurement, mercury, mercury analysis, atomic absorption spectrophotometry.

A CONTINUOUS MONITOR FOR HEXAVALENT CHROMIUM IN RIVER WATER

Battelle-Northwest, Richland, Wash., Pacific Northwest Lab.
D.W. Alton
Available from NTIS as BNWL-1168 $3.00 in paper copy, $0.95 in microfiche, 49 pages, AEC Research and Development Report BNWL-1168. (October 1969)

A continuous monitor for hexavalent chromium was developed and placed in routine operation at the automatic Columbia River Monitor Station (ACRMS), located at the 300 Area of Hanford, approximately 4 miles upstream from the nearest public water supply intake. Basically, the unit is commercially available equipment that uses a colorimetric method for continuous determination of Cr (plus 6) concentrations in river water. With a modified water filtration system and other changes, Cr (plus 6) in river water as low as 2 to 3 parts per billion can be measured reliably. A remote alarm system preset to actuate at a Cr (plus 6) concentration of 25 ppb provides the necessary time interval to enable water plants downstream to discontinue intake.

Keywords: water pollution, chromium compounds, industrial wastes, chromium, colorimetric analysis, chromium, chromates, monitors, corrosion inhibition, and nuclear reactors.

CHARACTERIZATION OF INDUSTRIAL WASTES BY INSTRUMENTAL ANALYSIS

Ontario Water Resources Commission, Toronto
H. A. Clarke
Proceedings of the Industrial Waste Conference, 23rd, Part 2, pages 26—34 (1968)

Instrumentation and techniques used in a large chemistry laboratory for the analysis and characterization of industrial wastes are described. Instrumentation, basic principles, and general methods of analysis are discussed, including polarography and atomic adsorption spectrophotometry for the analysis of metals, ultraviolet and infrared spectrophotometry for the identification of some organics, and gas and thin layer chromatography methods for the analysis of pesticide residues. In addition, examples of the application of this type of instrumentation to samples collected by carbon absorption are described.

Keywords: analytical techniques, industrial wastes, chromatography, spectrophotometry, polarographic analysis, metals, organic compounds, pesticide residues, and activated carbon.

THE FUTURE OF INSTRUMENTATION IN WATER POLLUTION CONTROL

Federal Water Pollution Control Administration, Cincinnati, Ohio
J. H. McDermott, D. G. Ballinger, and W. T. Sayers
Analysis Instrumentation, Vol. 6, pages 97—104 (1969)

Public recognition of the fact that our water resources are limited has led to a stepped-up program for preserving and enhancing the quality and value of this natural resource. This is reflected in recent federal and state legislation and in the size of the national clean-up program. Concomitant to this program is the need for field, laboratory, and aerial instrumentation capable of evaluating and controlling waste sources and the waters receiving these wastes. Automatic instrumentation available presently and in the future is discussed.

Keywords: instrumentation, management, planning, sanitary engineering, surveillance, and water pollution control.

ANALYTICAL INSTRUMENTS IN WATER POLLUTION CONTROL

Federal Water Pollution Control Administration, Cincinnati, Ohio. Analytical Quality Control Lab.
D. G. Ballinger
Analysis Instrumentation, Vol. 7, pages 242—246 (May 1969)

The application of various types of instruments to water analysis is described. The instruments reviewed are the gas chromatograph used for the determination of trace organic contaminants including pesticides and herbicides, the atomic absorption spectrophotometer used for the determination of metals in water, total organic carbon analyzers used for the determination of organic carbon content of water samples, ion meters used for the determination of cyanide, fluoride, nitrate, chloride, sulfide, calcium, and dissolved oxygen, and the infrared spectrophotometer used for the identification of organic pollutants. Consideration is also given to the Technicon Auto Analyzer and automatic titrators that have contributed to the automation and speedup of routine analyses. Further improvements in instrumentation are needed to extend the parameters that are covered and to further reduce the amount of manual labor involved in analyzing samples.

Keywords: laboratory equipment, chemical analysis, automation, instrumentation, gas chromatography, spectrophotometry, total carbon analyzer, ion meters, Auto Analyzer, and automatic titrators.

VALUE OF INSTRUMENTATION IN WASTE WATER TREATMENT

Albright and Firel, Philadelphia, Pa.
J. J. Salvatorelli
Journal of Water Pollution Control Federation, Vol. 40, No. 1, pages 101—111 (Jan. 1968)

Instrumentation is described as a valuable tool which if used properly by the operator will free him to perform duties requiring human attention. Mechanical, physical, and chemical methods may be used to control various processes within a system. Instrumentation for specific values are described; e.g., flow measurements, liquid levels in wet wells, operating pressure records, continuous recording, pH, temperature, and density analyzers. Specific applications are given for industrial waste treatment as well as domestic wastewater. The example given for industrial waste treatment is that of a metal waste containing heavy concentrations of cyanide, chromium, and other heavy metals. Each treatment phase depends on maintaining optimum pH to ensure the use of the minimum amount of chemicals needed to carry out the reaction. The burdensome job of maintaining optimum pH at the beginning of each treatment cycle was accomplished entirely by pH instrumentation and direct control of chemical application. The second illustration is a system designed primarily for monitoring an entire wastewater disposal system, including pumping stations, overflow diversion chambers, and the treatment plant. Because of the magnitude of the system, instrumentation and control at the wastewater treatment plant have been limited to only those functions necessary for proper plant operation. Costs are usually less than 5% of the total project costs.

Keywords: instrumentation, control system, wastewater treatment, flow, industrial wastes, sewage treatment, monitoring, operation and maintenance, sewers, centralized control, and meters.

AUTOMATIC COLORIMETRIC WATER ANALYSIS

A. Henriksen
Vattenhygien, 20, pages 102—110 (1964)

A routine laboratory for chemical analyses has been established at the Norwegian Institute for Water Research. Colorimetric methods are used most frequently, and tests were carried out with the Technicon Auto Analyzer to save time. It has so far been found that most of the manual colorimetric and some of the titrimetric and instrumental methods can be adopted to the Auto Analyzer, which has been in use for about 1 year. The advantages of using this instrument are also indicated. A table is included of water analyses that may be adapted to the Auto Analyzer, and the details and graphic results of automatic methods for iron, phosphate, and nitrate are provided.

Keywords: automated instruments and colorimetric analytical technique.

DETERMINATION OF TOTAL NITROGEN IN WATER BY MICROCOULOMETRIC TITRATION

Dohrmann Instruments Co., Mountain View, Calif.
R. T. Moore and J. A. McNulty
Environ Sci and Tech, Vol. 3, No. 8, pages 741—744 (Aug 1969)

A new and rapid instrumental technique has been developed to measure the total of both organically and inorganically bound nitrogen in water. Conceived as a replacement for normal Kjeldahl procedures, the system yields duplicate analyses down to 0.2 ppm in under 10 min. The sample is pyrolyzed over a granular nickel catalyst in a stream of humidified hydrogen, the bound nitrogen in the sample being converted quantitatively to ammonia and subsequently titrated electrochemically in a pH-sensitive cell. Suitable for use with partitioning procedures, specific scrubbers, and gas chromatography, the technique is capable of rapidly revealing the organic and inorganic nitrogen spectrum in water samples. Equivalent results are obtained where the sample matrices are the typical hydrocarbons used in partitioning.

Keywords: analytical techniques, chemical analysis, water analysis, nitrogen compounds, organic compounds, nutrients, nitrates, chromatography, ammonia, gas chromatography, nitrogen analysis and microcoulometric titration.

AN AUTOMATIC ABSORPTIOMETRIC METHOD FOR THE DETERMINATION OF NITRATE

D. R. Terrey
Analytica Chim. Acta, 34, pages 41—45 (1966)

A method has been developed for the determination of nitrate in the range 2-10 p.p.m., using the Technicon Auto Analyzer. The method involves reduction of nitrate to nitrite by hydrazine in alkaline solution, with copper as catalyst; the nitrite produced diazotizes sulphanilamide, and the product is coupled with N-(1-naphthyl) ethylenediamine to give a red dye, the absorbance of which is measured at 550 m μ. The method has been used successfully for the determination of nitrate in aqueous extracts of various kinds. A method described by A. Henriksen, (see Wat. Pollut, Abstr., 1966, 39, Abstr. No. 1893) is broadly similar, but intended primarily for sea-water samples.

Keywords: colorimetric, nitrate, catalyst and reduction.

FLUORIDE ELECTRODE AS A REFERENCE IN THE DETERMINATION OF NITRATE ION

Missouri Water Resources Research Center, Columbia
E. Manahan
Analytical Chemistry, Vol. 42, pages 128—129 (Jan. 1970)

The fluoride ion-selective electrode was used as a reference electrode for the standard addition determination of nitrate ion with the nitrate ion-selective electrode. The nitrate electrode was hooked to the measuring side of an expanded-scale pH meter and the fluoride electrode was connected to the reference side. The potential of the fluoride electrode was poised by the addition of a low concentration of fluoride ion to the solution to be measured.

At the concentration levels used, the nitrate electrode does not respond to fluoride ion nor does the fluoride electrode respond to nitrate ion. The electrode system is very stable and the liquid junction is eliminated. The concentration of nitrate ion is determined by adding a measured amount of standard nitrate to a known volume of unknown nitrate solution and calculating the original nitrate ion concentration from the shift in potential. Dilution effects and activity coefficient changes cancel. Nitrate ion concentrations in the range 0.00005 to 0.01 M were determined.

Keywords: nitrates, fluorides, analytical techniques, water analysis, electrodes, ions, volumetric analysis, water chemistry, pollutant identification, potentiometry, ion-selective electrodes, and standard addition.

AUTOMATED ANALYSIS OF AMMONIA IN WATER

National Inst. for Water Research, Pretoria (South Africa)
J. E. Harwood and D. J. Huyser
Water Research, Vol. 4, No. 10 pages 695—704 (Oct. 1970)

An automated method to determine ammonia-nitrogen over a wide concentration does not require changes in manifold. Sensitivity is altered by changes in the reagents. The most sensitive determination is based on the use of nitro-prusside as catalyst over the range 0-1 mg NH3-N per liter using a 15 mm flowcell and no range scale expansion. The phenol-hypochlorite reaction is almost specific for ammonia-nitrogen. The effect of metal ions was also investigated. An adequate buffering system should be used to eliminate the effect of sample pH.

Keywords: pollutant identification, ammonia, color reactions, colorimetry, chemical analysis, water analysis, nitrogen compounds, ammonium compounds, nitrogen, analytical techniques and ammonia analysis.

A RAPID METHOD OF DETERMINING AMMONIUM IN WATER WITH A UNIVALENT CATION GLASS ELECTRODE

Fisheries Research Board of Canada, Winnip (Manitoba). Freshwater Inst.
J. Barica
J. Fish Res Bd Can. 28 (5): pages 759—764 (1971)

The use of a univalent cation glass electrode for determining ammonium in water is described. The method enables direct determination of ammonium ion in concentrations above 0.5 mg/1 without any dilution or pretreatment of sample. A constant background of Na+ and K+ in samples is required, with concentration of K being lower than that of ammonium. For several types of natural and enriched waters with ammonium content up to 40 mg/1 NH4-N, the mean error by the method was plus or minus 4.9%.

Keywords: ammonium, cation, measuring electrode, glass electrode method, univalent cation.

AUTOMATED KJELDAHL ANALYSES OF NITROGENOUS MATERIALS IN AQUEOUS SOLUTIONS

National Inst. for Water Research, Pretoria (South Africa)
J. E. Harwood and D. J. Huyser
Water Research, Vol. 4, No. 8, pages 539—545 (August 1970)

A single manifold was developed that could be used for Kjeldahl analyses over a wide range of nitrogen contents. An automated method to determine total nitrogen on liquid samples containing a wide range of nitrogen is based on the separation of ammonia-nitrogen by distillation from the acid digest prior to the determination of the ammonia-nitrogen content. Sensitivity may be altered by changing reagents. The most sensitive method covered the range 0-20 mg per liter with a 15 mm flowcell and no range expansion.

Keywords: ammonia, nitrogen, chemical analysis, spectrophotometry, instrumentation, automation, laboratory tests, measurement and automated nitrogen analysis.

POTENTIOMETRIC NITRATE ANALYSIS: A FLOW-THROUGH ELECTRODE UNIT

New South Wales Dept. of Agriculture (Australia) Div. of Science Services
J. Milham
Analyst, Vol. 95, pages 758—759 (August 1970)

A flow-through electrode unit for use with a liquid ion-exchange nitrate electrode is described. Temperature control to within plus or minus 0.5°C at 25°C and reproducible stirring of the test medium give a mean coefficient of variation of 0.36 per cent for standards and 0.63 percent for plant extracts. The average time for each nitrate concentration measurement is halved.

Keywords: nitrates, electrodes, ion exchange, instrumentation, plants, and analytical techniques.

DETERMINATION OF NITRATE IN WATERS WITH THE NITRATE-SELECTIVE ION ELECTRODE

Wisconsin Univ., Madison, Sept. of Soils
D. R. Keeney, B. H. Byrnes and J. J. Genson
Analyst, Vol. 95, No. 1129, pages 383—386 (April 1970)

The Orion selective-ion nitrate electrode for determination of nitrate-nitrogen in water was tested and the results were compared with those obtained by phenoldisufphonic acid and steam distillation procedures. Recovery of added nitrate-nitrogen ranged from 83 to 105 percent with the ion electrode. However, results obtained on ground and surface-water samples were consistently lower than those obtained by the other two methods. The ion electrode may be useful for routine analysis of well and surface waters with nitrate-nitrogen concentrations above 10 mg/liter.

Keywords: nitrates, nitrogen, electrodes, chemical analysis, groundwater, surface waters and ion-selective electrodes.

SPECIFIC-ION ELECTRODE DETERMINATION OF NITRATE IN SOME FRESHWATERS AND SEWAGE EFFLUENTS

Pennsylvania State Univ., University Park, Dept. of Geochemistry and Mineralogy
D. Langmuir and R. L. Jacobson
Environmental Science and Technology, Vol. 4, No. 10, pages 834—838 (October 1970)

Thirty-seven waters with 1.5 to 122 ppm NO_3 were analyzed with a nitrate ion-selective electrode by the brucine method. Two electrode methods were evaluated. The K-gamma method involves making corrections for HCO_3 and C1- and for the effect of ionic strength on Gamma NO_3. C1- has a selectivity ratio of about 3 X 10-2, five times more serious an interference than previously reported. Gamma NO_3 is evaluated graphically from the specific conductance and the sample's prevalent chemical character. Agreement between the K-gamma and brucine methods was generally within 1 ppm at all NO_3 concentrations. An approximate electrode method gave results similar to the brucine values for samples above 50 ppm of NO_3, but was not reliable below that value. Advantages of electrode over the brucine method are: 1) measurements are generally unaffected by sample color or turbidity, 2) NO_3 concentrations of 1 to about 6000 ppm may be determined without sample dilution or concentration, 3) the method is rapid and portable, 4) procedures are simple but yield an accuracy comparable to that of the brucine method, and 5) reproducibility of measurements with the nitrate electrode is often better than ±1%.

Keywords: nitrates, sewage effluents, pollutant identification, analytical techniques, electrochemistry, electrodes, membrane processes, electrical conductance, carbonates, bicarbonates, chlorides, ions, brucine method, and chemical interference.

CONTINUOUS RECORDING OF THE AMMONIA CONCENTRATION IN NATURAL WATERS AND EFFLUENTS

T. G. Brydges and R. Briggs
Water Waste Treat., 12, pages 50—52 (1968)

A prototype instrument for the continuous recording of ammonia in water and effluents is described. Dissolved air and carbon dioxide are first removed in a current of helium. This is followed by quantitative oxidation of the ammonia to nitrogen by alkaline solium hypobromite. The nitrogen is removed by helium, and its concentration is determined by a diffusion katharometer. The instrument records in two ranges, which together cover up to 50 mg ammonia, as nitrogen, per litre, and it has operated on river water for periods of up to 10 days with an accuracy of ±0.1 mg per litre. A commercial prototype uses electrolytically generated hydrogen as the stripping gas, with a consequent increase in sensitivity.

Keywords: ammonia, ammonia analysis, instrumental ammonia analysis, ammonia-oxidation, nitrogen analysis, and nitrogen diffusion.

TOC, TOD, COD

APPLICATION OF A HIGH SENSITIVITY TOTAL ORGANIC CARBON ANALYZER

Beckman Instruments, Inc., Fullerton, Calif. Process Instruments Div.
R. H. Jones and A. F. Dageforde
Analysis Instrumentation, Vol. 6, pages 43—51 (1969)

The total organic carbon analyzer, developed at Dow Chemical, operates by first measuring total carbon and then determining inorganic carbon in a second operation. The organic carbon content is then arrived at by simple subtraction. The instrument is operated manually. In normal operation, total carbon is determined by measurement of CO_2 resulting from combustion and decomposition of carbon compounds in a catalyst-packed (cobalt oxide) column at high temperature (950°C). Measurement is by infrared instrumentation. Inorganic carbon is determined by CO_2 measurement where the CO_2 results from the breakdown of carbonates or the release of dissolved CO_2. This mode of operation limits the sensitivity of the instrument and requires the use of relatively small samples. On low level organic carbon samples the instrument can be operated at high gain with large samples. This method may improve the accuracy of analysis of organic carbon in surface waters and in other applications important to water pollution control.

Keywords: analytical techniques, organic carbon, pollutant identification, sewage effluents, industrial wastes, organic compounds, infrared radiation instrumentation, carbon dioxide, carbonates and total organic carbon.

ORGANIC MATERIAL ANALYZER MONITORS SHORELINE SEWAGE DISPOSAL

Chemurgic Council, New York
J. W. Ticknor
Water and Sewage Works, Vol. 119, No. 3, pages 50—51 (Mar 1972)

Scientists at the Woods Hole Oceanographic Institution, Massachusetts, are working on a project concerned with the healthful disposal of treated sewage and providing nutrients for increased shellfish culture along the eastern seaboard. Experimentation involves feeding treated sewage to algae and feeding the algae to shellfish (oysters, mussels, scallops) under controlled conditions. In order to determine what nutritive values the shellfish derive from the sewage-phytoplankton-sunlight system, the food chain is constantly monitored at selected points using a Perkin-Elmer Model 240 elemental analyzer. This instrument automatically analyzes organic compounds for carbon, hydrogen, and nitrogen content simultaneously, performing a complete analysis within 13 minutes. It is used, in this case, to determine levels and ratios of N and P present in algae, molluscs, and molluscs' detritus. The analytical method consists of: (1) burning the organic sample in an O_2 atmosphere aided by catalysts such as silver tungstate and magnesium oxide, (2) flushing the gaseous combustion products with a helium stream through a reduction tube, and (3) removing H, C, and N as the gaseous products move through a series of traps. The analyzer can be readily converted for oxygen analysis.

Keywords: chemical analysis, monitoring, nutrient cycling, food chains, organic compounds, instrumentation, analytical techniques, sewage, sewage effluents, sewage treatment, sewage disposal, marine algae, clams, mussels, oysters, eutrophication, organic carbon, elemental analyzers, and macroinvertebrates.

CARBON MONITOR

Automated Environmental Systems, Inc.
F. R. Boucher
Instruments and Control Systems, Vol. 43, No. 1, pages 22—23 (Jan 1970)

A new total organic carbon (TOC) monitor has been developed which provides continuous measurement with no manual pretreatment or manipulation. The instrument consists of a sample feed and pretreatment system which removes inorganic carbon from the effluent stream, an oxidation system which converts the organic carbon to carbon dioxide, and an infrared analyzer which measures the carbon dioxide and produces a signal directly proportional to TOC in the stream. The effluent produced by the monitor contains gaseous water, carbon dioxide and oxygen, plus oxidation products of noncarbonaceous compounds. The carbon dioxide in the effluent is proportional to the total organic carbon in the sample stream.

Keywords: carbon, organic matter, monitoring, infrared radiation, carbon dioxide, instrumentation, total organic carbon and infrared analyzer.

ANALYSIS OF MUNICIPAL AND CHEMICAL WASTE WATERS BY AN INSTRUMENTAL METHOD

Dow Chemical Co., Midland, Mich. Analytical Science Lab.
V. A. Stenger and C. E. Van Hall
Journal of the Water Pollution Control Federation, Vol. 40, No. 10, pages 1755—1763 (Oct. 1968)

An instrumental method based on a vapor phase oxidation mass reduction system utilizing carbon monoxide as a reaction product is discussed. Principle of operation and operating conditions is covered. The testing of samples includes primary and secondary municipal waste water, cellulose production wastes, and chemical wastes. Comparison between the instrumental (CO2D) and conventional (COD and TOC) tests are made. Results show comparable COD and CO2D values. A number of common compounds has shown results within 5% of the theoretical COD values. The results on some others particularly volatile compounds such as phenol or acetone may be low by 10-15%. The presence of chloride (500 mg/l NaC1) raises results by about 10 mg/l at the 100-200 mg/l COD level.

Keywords: carbon analyzer, organic carbon analyzer, oxidation-reduction system, waste water treatment, and instrumentation.

APPLICATION OF THE TOTAL CARBON ANALYZER FOR INDUSTRIAL WASTEWATER EVALUATION

Texas University, Austin
D. L. Ford
Proceedings of the Industrial Wastes Conference, 23rd, pages 989—999 (1968)

The carbon analyzer provides a rapid and simple means of determining the organic levels in aqueous solutions. The total organic carbon (TOC) test is free of many of the variables which affect the BOD and COD analyses. In attempting to correlate TOC to BOD or COD certain limitations should be recognized, namely: a portion of COD is attributable to inorganics; the

BOD and COD tests do not include the resistant organic compounds; and the BOD test is susceptible to many variables. Theoretically, the COD/TOC ratio ranges from zero, when the organic material is resistant to chemical degradation, to 5.33 for methane. Values cited for several industrial wastewaters range from 1.75 to 6.65. For waste streams of relatively constant character a COD-TOC relationship may be developed. It has been difficult to correlate BOD with TOC for industrial wastes, but relatively good correlations have been obtained with domestic wastes. Ratios of five-day BOD to TOC of 1.35—2.62 have been reported. Both the COD/TOC and BOD/TOC ratios decrease during biological oxidation.

Keywords: biochemical oxygen demand, chemical oxygen demand, industrial wastes, wastewater instrumentation, waste treatment, total organic carbon and correlation.

RAPID MEASUREMENT OF ORGANIC POLLUTION BY TOTAL ORGANIC CARBON AND COMPARISONS WITH OTHER TECHNIQUES

Geological Survey, Menlo Park, Calif.
J. W. Helms
U. S. Geological Survey Open-file report, 9 pages (May 21, 1970)

Among the techniques for measuring carbonaceous material in water, the TOC (total organic carbon) determination is probably one of the best in terms of speed and accuracy. As a means of monitoring waste discharge, the TOC method is the most applicable. Results can be obtained promptly to allow corrective measures to be made before significant impairment occurs in the receiving water. Waste discharging facilities can utilize on-site TOC monitors to shorten the time interval when improper treatment processes allow objectionable waste to be discharged. TOC monitors may also prove useful in the monitoring of various stages of waste treatment. Modifications of treatments could be initiated almost immediately to cope with changes in waste composition. Plant wastes for a particular process or product are generally uniform in content. If a correlation is established between methods, that correlation should hold until the process is changed. Where wastes contain a myriad or organic compounds if one or a few should change in concentration, good correlation should still be possible since the total composition remains fairly uniform. Municipal or sanitary wastes fall into this category.

Keywords: water analysis, organic matter, biochemical oxygen demand, oxygen demand, organic wastes, pollutant identification, organic loading, analytical techniques, chemical analysis and total organic carbon analysis.

INVESTIGATION OF ORGANIC POLLUTION OF SURFACE WATERS BY ULTRAVIOLET SPECTROPHOTOMETRY

Hydraulic Research Inst., Ostrava (Czechoslovakia)
M. Mvrka
J. Water Pollut Contr Federation, Vol. 41, No. 11, Part 1, pages 1923—1931 (Nov 1969)

To determine the organic content of surface waters, several methods may be employed, including ultraviolet spectrophotometry. Assuming that surface waters consist mainly of readily degradable organics and other lignum substances, three groups of surface water classifications were proposed. Absorbance spectra for each of the three ranges were 220 to 280 millimicrons for rivers with high concentrations of lignum sulfonates; and 270 millicrons for rivers which received additional waste products (phenol, etc.). Coefficients to convert absorbance to organic concentration are given. Experiments to confirm the proposed wavelengths were performed on the river Odra in the Central European region.

Keywords: pollutant identification, organic wastes, spectrophotometry, ultraviolet radiation, water pollution sources, sampling, laboratory tests and ultraviolet spectrophotometry.

ENERGY, TOTAL CARBON, AND OXYGEN DEMAND

Rice Univ., Houston, Texas, Dept. of Chemical Engineering
A. W. Busch
Proceedings Industrial Waste Conference, 20th (May 4, 5, 6, 1965), Purdue University, Vol. XLIX, No. 4, pages 457—469 (July 1965)

Certain concepts held basic to the measurement of organic pollution are emphasized and data relating to the use of parameters other than oxygen consumption for organic pollution definition and measurement are presented. Only soluble organics are of basic significance in biological oxidation. Work at Rice University has resulted in the definitions of two methods for the measurement of biodegradable soluble organics: (1) a materials balance technique of extreme precision, suited only for research work, and (2) a rapid mass culture technique of plus or minus 10 percent precision, suitable for waste characterization, process design, and plant control. The application of thermodynamic concepts derived for reversible reactions at equilibrium to biological reactions which operate at a point remote from equilibrium seems hazardous. Total carbon changes during bio-oxidation provide a significant and useful measure of the reaction and the biodegradable organic content. The ease and rapidity of the mass culture technique in conjunction with the total carbon analyzer offer an exciting prospect for definitive pollution measurements.

Keywords: organic matter, oxygen demand, energy, carbon, thermodynamics, biological treatment, biochemical oxygen demand, biodegradation, chemical oxygen demand, waste water treatment, oxidation, organic wastes, pollutant identification, total carbon, substrate, total carbon analyzer and organic pollution.

SYSTEM FOR MEASURING ORGANIC CONTENT OF WATER

Envirotech Corp., Palo Alto, Calif. (Assignee)
M. M. Zuckerman and A. H. Molof
U. S. Patent No. 3,635,564, 4 pages; official gazette of the United States Patent Office, Vol. 894, No. 3, pages 1037—1038 (Jan. 18, 1972)

A system for monitoring the performance of a water treatment facility is provided. The soluble organic content of water is measured by a refractometer which compares the refractive index of a water sample with a known sample. Electrical conductivity measurements and turbidity measurements are compared with known samples.

Keywords: patents, organic matter, conductivity, monitoring, treatment facilities, water treatment, water properties, organic wastes, biochemical oxygen demand, dissolved solids, turbidity and measurement.

TOC ANALYSIS FOR MONITORING TERTIARY TREATMENT PROCESS EFFICIENCY

Beckman Instruments, Inc., Fullerton, Calif.
R. H. Jones
Water and Sewage Works, Vol. 119, No. 3, pages 72—74 (March 1972)

Total organic carbon (TOC) is the best measurable parameter that can be used for monitoring the efficiency of the tertiary treatment process in removing organics which survive the secondary treatment process. TOC and COD analyses were made at ten sample points in a carbon bed tertiary treatment process. TOC determinations were made with a Beckman Model 915 total organic carbon analyzer which is designed to quantitatively measure organic carbon in aqueous solution. With this analyzer, one sample is burned at high temperature (950 degrees C) to produce CO_2 which is carried through the flow cell of a non-dispersive infrared analyzer. Recorded peak heights from the TWC samples are proportional to the total carbon and inorganic carbon, respectively, in the aqueous samples. The difference between the two recorded peaks indicated TOC. Pretreatment of samples with hydrocholoric acid allows a more sensitive means of inorganic concentrations. This also permits the use of larger samples and can increase instrument sensitivity to 0-10 mg/l full scale.

Keywords: sewage, instrumentation, sewage treatment, influent streams, inflow, tertiary treatment, sewage effluents, monitoring, carbon dioxide, water quality control, pollutant identification, carbon, carbonates, chemical oxygen demand, total organic carbon, inorganic carbon, total organic carbon analyzer, infrared analyzer, precision and detection limits.

THE TOTAL ORGANIC CARBON ANALYZER AND ITS APPLICATION TO WATER RESEARCH

Washington Univ., Seattle, Water Biology
R. F. Christian, R. M. Emery and E. B. Welch
Journal Water Pollution Control Federation, Vol. 43, No. 9, pages 1834—1844 (Sept. 1971)

Because of the system provided for carbon combustion, and the method used for CO_2 detection by a nondispersive infrared analyzer requiring no monochromator, the total organic carbon (TOC) analyzer seems to offer the most rapid and accurate analysis available for organic carbon. Allowing time for warm-up of the combustion furnaces, a single carbon value can be determined in 2 min. with an accuracy of 1 percent of full scale and a sensitivity of plus or minus 1 mg/l. Studies of the IVA showed that total and organic carbon concentrations determined by the TOC analyzer are positively correlated with both long-term (R=0.72, S=0.12 mg biochemical oxygen demand) (BOD)/day/day) and 5-day (R = 0.69, S = 0.15 mg BOD/day/day) BOD rates. Chemical oxygen demand (COD) was also shown to be strongly correlated with total (R=0.93, SE=25.8 mg COD/L) and organic (R=0.93, SE=26.1 mg COD/L) carbon (as determined by a total carbon analyzer) in municipal wastewater samples from three cities in Michigan. More investigations into the relationships between carbon content and oxygen demand may possibly allow development of reliable prediction factors and equations for the renovation and design of water and wastewater systems that receive interference from biological and chemical oxidation mechanisms.

Keywords: instrumentation, analytical techniques, infrared radiation, on-site investigations, temperature, sampling, absorption, condensation, oxidation, biochemical oxygen demand, chemical oxygen demand, carbon dioxide, pollutant identification, total organic carbon analyzer.

RAPID INSTRUMENTAL MEASUREMENT OF ORGANIC LOAD IN WASTE WATERS

Rocketdyne, Canoga Park, Calif.
I. Lysyj, K. H. Nelson and H. Snell
Journal of the Water Pollution Control Federation, Vol. 41, No. 5, pages 831—835, (May, 1969)

Equipment, procedures and calculations of a pyrographic technique for the determination of total organic content of waste waters are described. Results are calculated as oxygen demand similar to those from the biochemical oxygen demand (BOD) test. Application of this technique to raw waste water and primary treated effluents produced results differing by only 5% from parallel standard 5-day BOD determinations. Relative amounts of biodegradable and nonbiodegradable components of secondary treated effluents were predicted when the pyrographic technique results were compared with 5-day BOD test results.

Keywords: biochemical oxygen demand (BOD), laboratory equipment, effluents, organic matter, organic loading, treatment facilities, instrumentation, measurement, analytical techniques, pyrolysis, pyrographic technique and non-biodegradable matter.

PYROLYTIC ANALYZER DETECTS ORGANIC MATTER IN WASTEWATERS

North American Rockwell Corp., Canoga Park, Calif. and Los Angeles Bureau of Sanitation, Calif.
K. H. Nelson, I. Lysyj and J. Nagano
Water and Sewage Works, Vol. 117, No. 1, pages 14—18 (Jan. 1970)

Operation of wastewater treatment plants needs rapid acquisition of data on essential parameters and variables including the organic load in the process stream. The organic load can be quickly measured with a new instrument designed on the principle of fragmentation of the organic matter by direct pyrolysis in the presence of water. The measurable volatile organic fragments produced are summed with a detector specific for organics. These data can be converted and expressed as BOD through calibration. The primary advantage of the organic analyzer for measurement of the organic load is its capability for instantaneous or continuous data acquistion, and elimination of extensive sample preparation or pretreatment. The simplicity and compactness of the instrument is an added major advantage. A series of four to six injections into the pyrolysis chamber is adequate for waste water analyses. Field tests of the pyrolytic analyzer were made on raw sewage samples primary and secondary effluents at the Hyperion treatment plant, Los Angeles, California. Pyrolytic analyzer results were compared to regular BOD 5 test results. For the raw sewage tests the average difference was 4.1%; for primary effluents—6.8%; for secondary effluents—the pyrolytic results average about twice the BOD 5 results. Possible reasons for discrepancies are discussed.

Keywords: waste water treatment, organic matter, volatility, effluents, laboratory equipment biochemical oxygen demand, chemical oxygen demand, treatment facilities, operational, pretreatment, organic loading, pyrolysis, pyrolytic analyzer, organic analyzer, instrument design, BOD5 test, hydrogen—flame ionization detector, raw sewage, primary effluents, secondary effluents and functionality tests.

AN AUTOMATED SYSTEM FOR THE DETERMINATION OF CHEMICAL OXYGEN DEMAND

Upper Thames Main Drainage Authority, Birmingham (England)
A. E. Hey, A. Green, and N. Harkness
Water Research, Vol. 3, pages 873—886 (1969)

Although equipment for automated determination of chemical oxygen demand (COD) is now commercially available, it is not suitable for a continuous analysis of effluents. The described procedure comprises metering of volume samples digested with mercuric sulfate, potassium dichromate, and sulfuric acid in mixture pots. The solution is pumped through a 40-foot glass coil suspended in a fluidized sand bath heated to 160°C. The cooled solution is passed through a colorimeter that records the reduction of dichromate. The COD is computed by reference to the peak heights given by standards. The modification of the method eliminates the peristaltic pump, an item responsible for frequent breakdown of the assembly.

Keywords: chemical oxygen demand, measurement, sewage effluents, analytical techniques automation, colorimetry, instrumentation, dichromate reduction, and automated apparatus.

AUTOMATIC MEASUREMENT OF TOTAL OXYGEN DEMAND

Dow Chemical Co., Midland, Mich.
D. A. Clifford
Proceedings of the Industrial Waste Conference, 23rd, pages 832—848 (1968)

The need for a more accurate method of determination of oxygen demand is emphasized. To meet this need, the Dow Chemical Company has developed the total oxygen demand (TOD) analyzer. This instrument affords a very rapid and precise method for determination of oxygen demand. The developed method measures directly and quantitatively the amount of gaseous oxygen required to oxidize the nonaqueous constituents of a water sample. The reaction efficiency is very nearly equal to the theoretical without significant interference from the common sources. Because of the severity of oxidizing conditions (i.e., 900°C over platinum), the method has been named the total oxygen demand method. The TOD analyzer is fully automatic in its functions of sampling and analyzing, requiring a total time of 2 to 4 minutes per sample. Correlation of this method with the standard dichromate COD method has been very good on wastewater analysis. The TOD analyzers have successfully operated over several instrument years as a device for laboratory and process analysis of water and wastewater.

Keywords: chemical oxygen demand, analysis, wastewater treatment, instrumentation, total oxygen demand (TOD), TOD oxidation reaction, calibration curve, reaction efficiency, and plant effluent.

AUTOMATED MEASUREMENT OF COD

M.H. Adelman
Water Wastes Engineering, 5, No. 6, pages 52—55, (1968)

An illustrated description with flow diagrams is given of a method for determining chemical oxygen demand (COD) using the Auto Analyzer, which is a modification of automatic procedure already reported. It involves mixing the sample with a mercuric salt to eliminate interference by chloride, adding acid, dichromate, and silver sulphate as catalyst, digesting the mixture in a heating bath of 155°C, cooling, and measuring the transmission 420 mμ or 600 mμ in a colorimeter. One wavelength (420 mμ) is used in combination with low concentrations of dichromate for measuring COD values below about 1000 to 500 mg per litre, and the other is combined with higher dichromate concentrations for measuring values up to 50,000 mg per litre. Mean percentage deviations between results from this method and from manual methods are quoted for a wide range of values.

Keywords: instrument, chemical oxygen demand (COD), and automatic equipment.

ANALYSIS OF MUNICIPAL AND CHEMICAL WASTE WATERS BY AN INSTRUMENTAL METHOD FOR COD DETERMINATION

V.A. Stenger, and C.E.V. Hall
J. Water Pollution Control Fed., 40, pages 1755—1763, (1968)

Experiences are reported using the new 2-minute instrumental combustion method for determination of COD to analyze various streams of wastewater from a plant of the Dow Chemical Company and a municipal sewage works (both in Midland, Mich.). The results were compared with data from the standard COD test and determinations of total organic carbon. Results from the new test lead to significantly higher than those from the standard test, indicating that some compounds are oxidized less completely in the standard method. In sewage effluents, the higher values in the new method are explained by the inclusion of the oxygen demand due to nitrogen-bonded hydrogen in compounds such as urea, ammonia, and proteins. In the new method there is no interference from carbonate.

Keywords: total oxygen demand and standard test.

A COMPACT POTENTIOMETRIC SENSOR OF NOVEL DESIGN (In Situ Determination of pH, pS^{2-}, and Eh)

M. Whitfield
Marine Biological Association, Plymouth (England)
Limnology and Oceanography, 16(5), pages 829—837 (Sept. 1971)

A rugged, compact probe (2 cm overall diameter, 9 cm overall length) is described that enables pH, pS^{2-}, and Eh to be measured in situ. A miniature glass electrode is mounted in an epoxy resin body to which the metal electrodes are cemented. The glass electrode is mercury filled and has a cylindrical sensing membrane. The resulting probe is relatively insensitive to vibration and to changes in light intensity, and the glass electrode equilibrates rapidly to ambient temperature and pressure changes. Construction details are given. With appropriate holders, the probe can be used for measurements in the water column, in the sediment, or in the intertidal zone. The performance of the unit is illustrated by data from a stagnant basin model and from an estuarine survey.

Keywords: instruments, sensors, water-quality measurements, pH environmental conditions, in situ potentiometric sensor, Eh, and pS^{2-}.

pH INSTRUMENTATION AND AUTOMATION IN THE TREATMENT OF TRADE WASTES

A. C. Stewart
Water Pollution Control, Vol. 67, No. 3, pages 265—268 (1968)

A clear description of the control instruments available and useful advice on the selection and application of neutralization agents for the control of pH are presented. The dip-type electrode system described is suitable for applications where the velocity of the liquid is low. The flow-type electrode system gives less trouble as the electrodes are mounted on the top of the sampling chamber, but in this the time delay required for the liquid to reach the electrodes is sometimes unacceptable. The paper further discusses the pH meter as a device for transforming a purely static voltage into an equivalent value of electric power. Electro-pneumatic control and electric automatic two- and three-term controls used in the pH control of the effluent are then considered. The selection and application of reagents in the pH control of the trade effluents are discussed briefly. Also mentioned is the redox controller that is used to control the oxidation-reduction reactions.

Keywords: instrumentation, automation, electrodes, industrial waste, hydrogen ion concentration, dip-type electrode, flow-type electrode, redox-controller, and reagents.

RAPID PHOSPHATE DETERMINATION BY FLUOROMETRY

Missouri University, Columbia, Dept. of Chemistry, and Oak Ridge National Lab., Tennessee Division of Analytical Chemistry
J. C. Guyon and W. D. Shults
J. American Water Works Association, Vol. 61, No. 8, pages 403 and 404 (Aug. 1969)

To measure phosphate contamination, two similar fluorometric procedures are offered, one for low concentrations and one for high. The methods proposed were evaluated by adding known amounts of phosphate to volumetric flasks and carrying out the analysis as described in the recommended procedures. An average relative error of 1 to 5% was observed for the one system, and 2% for the other. These suggested methods provide survey techniques for phosphate determinations over a wide range of concentrations. The methods are manipulatively simple and should be readily adaptable to field survey or to conventional or automated laboratory situations.

Keywords: analytical techniques, chemical analysis, phosphates, fluorometry, pollutant identification, water chemistry, water quality, and phosphate analysis.

METHOD SELECTION STUDY I: A COMPARISON OF THREE MODIFICATIONS OF THE SINGLE REAGENT METHOD FOR SOLUBLE ORTHOPHOSPHATE

Federal Water Pollution Control Administration, Cincinnati, Ohio Analytical Quality Control Lab.
J. A. Winter and R. L. Booth
Available from: EPA WQO, Analytical Quality Control Lab., 1014 Broadway, Cincinnati, Ohio 45202, 40 pages (April 1969)

A round-robin test was conducted by the Analytical Quality Control (AQCL) Laboratory on three modifications of the mixed reagent method of analysis for soluble orthophosphate for the purpose of establishing an FWPCA interim official method. The tests were conducted on spiked distilled water samples, spiked and unspiked river water, spiked and unspiked seawater, and, in one case, sewage effluent. Based on the data, which are included in graphs and tables, the method of Murphy and Riley gave the best precision and accuracy and the least bias and therefore was selected as the FWPCA interim official method.

Keywords: phosphates, water analysis, fresh water, seawater, sewage effluents, surface water, statistical methods, iron, orthophosphates, chemical recovery, FWQA methods, distilled water, and chemical interference.

POTENTIOMETRIC STUDIES WITH A LIQUID ION-EXCHANGE LEAD-SELECTIVE ELECTRODE

Kentucky University, Lexington, Department of Chemistry
Lal Sudarshan and Gary D. Christian
Analytica Chimica Acta, Vol. 52, No. 1, pages 41–46 (Oct. 1970)

The performance of the Orion liquid ion-exchange lead-selective electrode has been determined in terms of the working concentration range of lead ions, its selectivity to other ions, its response time, the effective pH range in which it can be used, and its use in potentiometric titrations. The electrode exhibits relatively high response to monovalent cations and can be used in the potentiometric titration of alkali metals, thallium (I), silver (I), and ammonium ions with sodium tetraphenylboron, as well as for titrations of lead (II) with various solutions. The electrode functioned adequately at concentrations of 2 x 10 to the minus 5th power to 10 to the minus 2nd power M, but optimal results were obtained at concentrations of 10 to the minus 4th power M or greater.

Keywords: electrodes, ions, analytical techniques, alkali metals, ammonium compounds, hydrogen ion concentration, volumetric analysis, chemical precipitation, lead, thallium, silver, and chemical interferences.

SPECIFIC ION ELECTRODES

F.W. Karasek
Research/Development, Vol, 21, No. 6, pages 71, 72, and 74 (June 1970)

This paper is a tutorial review of the history, characteristics, applications, and future of specific ion electrodes. In addition to their use for laboratory analytical measurements, electrodes are now being adapted for applications in continuous process control. These electrodes appear to be well established in a process monitoring version—hydrogen, sodium, and chloride ion electrodes. The most significant recent addition has been the potassium electrode. The sensor exhibits high selectivity to potassium in the presence of large amounts of other ions. Corning has developed a micro-electrode with dimensions in the micron range. It is designed to measure chemical and electrical changes in living cells and should prove quite useful in biological research.

Keywords: electrodes, analytical techniques, nitrates, fluoride, hydrogen, sodium, chlorides, potassium, biochemistry, hydrogen ion concentration, and chemical interferences.

ION-SELECTIVE ELECTRODES

R.J. Simpson
Effluent Water Treatment Journal, 11, pages 96–98 (1971)

An investigation of ion-selective electrodes was made to consider their application to problems of continuous chemical analysis of effluents and process solutions. These electrodes have a high sensitivity and rapid response but are not completely selective. However, if it is known that interfering ions will be present only in insignificant concentrations, use of a monitoring electrode will be a possibility.

Keywords: instruments, continuous, specific ions, interferences, and calibration.

ION-SELECTIVE ELECTRODES: INDUSTRIAL APPLICATIONS

T.S. Light
Water Engineering, 6, No. 9, pages 33—37 (1969)

The author describes the various types of ion-selective electrodes that are available commercially and discusses their use in monitoring industrial processes and wastewaters.

Keywords: continuous, ions, monitoring, industrial water, wastewater, and commercially available.

ION-SELECTIVE ELECTRODES—THEORY AND APPLICATIONS IN WATER ANALYSIS

J. B. Andelman
Water Pollution Control, 40, pages 1844—1860 (1968)

The author reviews the principles of operation of membrane-type ion-selective electrodes, discusses various calibration techniques and the effect of interfering ions, and gives examples of their use in the analysis of water and wastewater. A bibliography of 35 references is appended.

Keywords: membrane-type ion-selective electrodes, calibration, interferences, monitoring, continuous, analysis, and wastewater.

POSSIBILITY OF DETERMINING THE CONCENTRATION OF SUSPENDED MATTER BY AN OPTICAL METHOD

Akademiya Nauk SSSR, Moscow, Institut Okeanologii
A. N. Maksimov and M. M. Shlafman
Oceanology (USSR), Vol. 9, No. 4, pages 565—569 (1970)

A method is suggested for determining the concentration of suspended matter in seawater from values of the attenuation coefficients for light at two wave lengths. Curves for gradiations of concentration were constructed. The rather laborious determination of the concentration of suspended matter by weighing filters is simplified by the method, which also makes possible the elimination of the calculation of particle diameter in determining the concentration of suspended matter from the light attenuation coefficients.

Keywords: suspended load, turbidity, analytical techniques, instrumentation, optical properties, seawater, light intensity photometry, water quality, light penetration, and turbidimeters.

MEASUREMENT OF SUSPENDED SOLIDS CONCENTRATIONS IN SEWAGE BY USE OF A DEPOLARIZATION METHOD

Newark College of Engineering, N. J. Department of Civil and Environmental Engineering
J. W. Liskowitz and G. J. Franey
Environmental Science and Technology, Vol. 6, No. 1, pages 43—47 (Jan. 1972)

The depolarization of back-scattered polarization radiation was used to measure the concentration of suspended solids in sewage. The effect of such factors as variations in the particle size of the suspended solids, solids density, color of the samples, refractive index of the medium, sample flow, and coated optical windows of the sample cuvettes on the relationship between the degree of depolarization and suspended solid concentration was investigated. Sewage samples taken from both the Middlesex County Sewerage Authority's plant in Sayreville, New Jersey (influent, effluent, activated-sludge pilot-plant effluent, and sludge from the clarifiers) and the Bernardsville, New Jersey plant (effluent, influent, and activated sludge) were analyzed. Depolarization measurements were performed, with photomultipliers having a mercury source for polychromatic radiation. Membrane filters were utilized in the gravimetric determination of suspended solids and in the determination of dissolved solids. Refractivity was measured with a differential refractometer, and the density of the suspended solids with a density gradient column. Size distribution was measured with a Cahn no. 2800 particle sedimentation accessory, and the distribution patterns were provided by computer. Suspended solids concentrations that range from a few parts per million to 5000 ppm by weight can be measured by use of the depolarization technique. The relationship between the degree of depolarization and concentration of suspended solids in sewage samples appears unaffected by the size distribution of the particles, density variations, source of samples, color variations, and organisms and aggregates generally found in sludge samples.

Keywords: sewage, industrial wastes, domestic wastes, measurement, effluents, activated sludge, sewage sludge, photometry, refractivity, radiation, density, opacity, color, water analysis, membranes, filters, computers, distribution patterns, particle size, sampling, membrane processes, suspended load, particulate matter, depolarization, polarized radiation, back-scattered polarized radiation, and refractometers.

SUSPENDED SOLIDS MONITORING: A COMPARISON BETWEEN THREE INSTRUMENTS

G. Fleming

Water and Water Engineering, 73, pages 377—382 (1969)

Procedures adopted in, and the results obtained from, the use and comparison of three instruments for continuous measurement of suspended solids in the river Clyde are described. Estimations of the suspended sediment load based on the monitored concentration were higher than those based on the rating curve method. The instruments used are illustrated, and include the Southern Analytical monitor, the Davall siltmeter, and a newly developed instrument.

Keywords: suspended solids, monitor, continuous, instruments, Southern Analytical monitor, and Davall siltmeter.

ANALYSIS OF WATER FOR MOLECULAR HYDROGEN CYANIDE

North American Rockwell Corp.
Rocketdyne Division, Athens, Ga.
K. H. Nelson and I. Lysyj

Journal Water Pollution Control Federation, Vol. 43, No. 5, pages 799—805 (May 1971)

An analytical technique to measure concentrations of molecular hydrogen cyanide at levels of less than 100 parts per billion has been developed. The method used combines vapor phase equilibrium techniques with highly sensitive amperometric techniques to measure sparged HCN with a rotating gold anode by measuring the current output of the system. Calibration of the system was accomplished using synthetic solutions of known composition. Synthetic unknowns were then tested, as well as fresh water from Sespe Creek in Ventura County, Calif. Synthetic samples of pH 6.1, 7.2, and 8.2 had standard deviations of 1.42, 2.59, and 3.12 respectively. The fresh creek water, to which known amounts of cyanides were added, had a pH of 8.2 and a standard deviation of 1.35. Current responses of a number of possible interfering ions were also measured. It was determined that H2S, in levels greater than the concentration level of HCN, could interfere with the readings. In concentrations below that of HCN, H2S was shown to have no effect on the readings. Present detection limits seemed to have been established by the techniques of handling and transferring nanogram quantities of the desired species. Therefore, improved handling techniques should provide the procedure with considerably more resolution.

Keywords: toxicity, chemical wastes, wastewater (pollution), aquatic environments, analytical techniques, instrumentation, water analysis, gas chromatography, polarographic analysis, calibrations, electric currents, cathodes, anodes, temperature, hydrogen ion concentration, water quality, pollutant identification, and hydrogen cyanide.

PHENOL ANALYSIS—SOME ANALYTICAL CONSIDERATIONS

General Electric Co., Re-Entry & Environmental Systems Division, Environmental Science Lab., Philadelphia, Pa.
R. J. Starkey, Jr.

Sensing of Environmental Pollutants, Joint Conference, Unbound Papers (Held in Palo Alto, Calif., Nov. 8 - 10 1971). Sponsored by American Chemical Society, American Institute of Aeronautics and Astronautics, U.S. Environmental Protection Agency, Institute of Electrical and Electronic Engineers, Instrument Society of America, U.S. National Aeronautics and Space Administration, and U.S. National Oceanographic and Atmospheric Administration. In: AIAA Paper No. 71-1036, 10 pages,(1971).

The contamination of potable water supplies with halogenated phenols in concentrations of 2 to 10 parts per billion (ppb) produces objectionable tastes and odors capable of influencing consumer acceptability. A routine analysis by the distillation/four-aminoantipyrine method is limited by lack of sensitivity and subject to interference by aryl amines. This has been overcome by developing a continuous liquid-liquid extraction system to selectively isolate phenols and eliminate major interfering substances. Stable reagents have been formulated to reduce blank color and extend sensitivity. Equipment suitable for the analysis of phenols at the 1 ppb level or less in 20 minutes is described.

Keywords: water pollutants, phenol, instruments, potable water odors, analysis equipment and methods, and taste.

THE DETERMINATION OF CYANIDE IONS IN WATERS AND EFFLUENTS BY AN AUTO-ANALYZER PROCEDURE

P. Casapieri, R. Scott, and E. A. Simpson
Analytica Chimica Acta, Vol. 49, pages 188–192, (Jan. 1970)

After a review of analytical methods for cyanide determination, the conclusion was reached that the most satisfactory colormetric procedure is the Aldridge method, which is based on the Koenig synthesis. In this procedure, cyanide is brominated to cyanogen bromide, excessive bromine is removed by a reductant, and cyanogen bromide is coupled with pyridine and an aromatic amine to give a colored complex. In order to handle large numbers of samples, this method was adapted for use with the auto-analyzer. An important feature of the procedure is the distillation stage, which not only improves the selectivity of the method but also eliminates the necessity of filtering samples containing particulate matter. The distillation stage is designed to give a sample rate of 40 samples/hour. Analysis of 1000 water samples (mostly trade effluents) by manual methods and by using the auto-analyzer showed excellent correlation between the results. The range of 0.5 to 10 ppm of cyanide ions was of primary interest, but it was found that Beer's law was obeyed up to 40 ppm of cyanide without any change within the system. Tables are included that show the results of the tests, as well as interferences that result from lead, nickel, copper, mercury, cyanate, thiocyanate, thiosulfate, bisulfate, nitrite, hypochlorite, formaldehyde, and phenol ions.

Keywords: automation, effluents, colorimetry, wastewater (pollution), sewage effluents, trace elements, auto-analyzer, cyanide, interference, and Aldridge method.

CONTINUOUS MONITORING OF AROMATIC COMPOUNDS IN WATER BY DIFFERENTIAL PHOTOMETRY

DuPont de Nemours (E. I.) and Co., Wilmington, Delaware
R. S. Saltzman
Analysis Instrumentation, Vol. 6, pages 79–85 (1969)

The monitoring of plant effluents for the presence of aromatic compounds is complicated by the presence of these compounds in the incoming water. However, by continuously monitoring the UV absorption of the influent and effluent, the difference in absorption at the two points provides a measure of the plant contribution to water pollution. The systems in use at DuPont in Wilmington, Delaware, employ either dual-beam or split-beam analyzers. Where high sensitivity is required, the system incorporates an automatic zero adjustment. For monitoring monocyclic aromatic hydrocarbons, the 254 mu line from a mercury lamp is used as the UV source. However, where polycyclic aromatic, phenol, or pyridine are present, erroneously high analyses may result. But even with this limitation, the concentration of components in the effluent may be constant so that the monitor can be calibrated to measure total concentration. Specific monitoring of low concentrations of phenols can be accomplished by measuring the characteristic wave length shift of phenol with pH. This method consists of measuring the difference in UV absorption of a sample made highly basic and then made slightly acid. Since only phenol shows this basochromatic shift, the method is highly selective. Schematics of the monitoring systems are shown.

Keywords: industrial wastes, phenols, photometry, monitoring, instrumentation, hydrogen ion concentration, automation, ultraviolet absorption, benzene, toluene, xylene, and pyridine.

ANALYTICAL EVALUATION OF A CYANIDE-ION SELECTIVE MEMBRANE ELECTRODE UNDER FLOW-STREAM CONDITIONS

Imperial College of Science and Technology, London (England) Department of Chemistry
B. Fleet and H. von Storp
Analytical Chemistry, Vol. 43, No. 12, pages 1575—1581 (Oct. 1971)

The evaluation of a silver sulfide-silver iodide membrane electrode as a continuous monitor for cyanide ion has shown that it is well suited for the measurement of cyanide in the concentration range (0.01 to 0.000051 m). An Orion Model 94-06 electrode was modified for continuous analysis by fitting a flow-through cap onto the membrane face. This was used with a Technicon Auto-Analyzer. An Orion Model 801 pH meter was used for potentiometric measurements. The procedure was to feed adjusted ionic strength buffer and sample as an air segment stream to the mixing coil. The segmenting gas and a portion of the solution are led to waste before reaching the electrode, and the residual solution is passed through the flow cell. Flow rate through the electrode is controlled by passing the exit line back through the pump. Serious anion interferences are encountered only from iodide and sulfide ions. A detailed study of the values obtained for the interference from iodide indicates that the potential-determining mechanism is more complex than the simple replacement reaction and involves a contribution from the direct displacement reaction.

Keywords: membrane processes, electrodes, pollutant identification, ions, ion exchange, membranes, monitoring, water analysis, potentiometers, calibrations, sulfides, cyanides, ion selective electrodes, iodide, and chemical interference.

INSTRUMENTATION FOR HYDROGEN SULFIDE MEASUREMENTS

Los Angeles Bureau of Sanitation, Calif.
F. Garber, J. Nagano, and F. F. Wada
Journal Water Pollution Control Federation, Part II, R209—R220, Vol. 42, No. 5 (May 1970)

The generation and release of hydrogen sulfides with subsequent odor and corrosion problems are a factor of concern in almost all wastewater systems, but particularly in areas where organic strength is high and average wastewater temperatures exceed 70 to 72 degrees F. Although previous work provided considerable insight into the mechanisms of sulfide generation and release, studies of these specific problems require extensive action and continuous testing capabilities. A number of sulfide test procedures have been developed over the years. Each of these has been of value under certain conditions, often satisfying needs for portability, low initial cost, and spot testing, as well as the more sophisticated continuous operation.

However, in-depth studies ultimately require an accurate automated continuous testing capability. For continuous measurement, a lead acetate tape, an early coulometric instrument, and the present coulometric instrument (capable of both liquid and gaseous phase analysis) have been examined. The improved automated lead acetate method has had wide applicability where the concentration range was predictable and specific reaction with hydrogen sulfide was important; however, the current coulometric method appears to be the most accurate.

Keywords: instrumentation, hydrogen sulfide, measurements, analysis, testing, wastewater treatment, sewage, test procedures, volumetric analysis, sewage treatment, detection, and inorganic sulfide.

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EVALUATION OF AN AUTOMATIC CHEMICAL ANALYSIS MONITOR FOR WATER QUALITY PARAMETERS

New York State Department of Health, Albany, Division of Labs and Research
J. E. O'Brien and R. A. Olsen

Journal Water Pollution Control Federation, Vol. 42, No. 3, Part I, pages 380—390 (1970)

In 1968 the Canada Center for Inland Waters (C-CIW) undertook a systematic monitoring of Lakes Ontario, Erie, Huron and Superior in a study of the major (Ca, Mg, Na, K, SO4, C1, HCO3 and F) and trace (Zn, Cu, Pb, Fe, Ni, Cr, Mn and Sr) elements. The data gathered on major elements during the period July to November 1968 were examined and the results compared on a lake-wide basis with earlier compilations to appraise recent trends and changes in the composition of these waters. Because the concentrations of all major ions for which data are available in Lake Superior have not changed for the last 70-80 years, their levels are apparently controlled by the balance between the amount of dissolved substances added by runoff from the drainage basin and that lost through St. Mary's River. Chloride and sulphate have increased in Lakes Michigan and Huron. This increase is most likely caused by human activities. In Lakes Erie and Ontario, all the major ions except bicarbonate and magnesium have shown a dramatic increase since 1910. Previous to that, the Lakes were essentially unaffected by human activities. The median values of minor elements (excepting Sr) is generally below 10 micrograms/liter in the Great Lakes. Sorption by oxides of manganese and iron and by suspended organic and inorganic material seems a plausible mechanism for the removal of minor elements from the lakes.

Keywords: monitoring, water quality, chemical analysis, data collections, control systems, measurement, colorimetry, automatic control, data processing, and New York.

AUTOMATED POTENTIOMETRIC TECHNIQUES FOR THE ON-SITE MONITORING OF ANION CONCENTRATIONS IN WATER

Missouri Water Resources Research Center, Columbia
E. Manahan

Available from the Clearinghouse as PB-192 809, $3.00 in paper copy, $0.75 in microfiche.
Completion Report (1970) OWRR Project B-023-MO(4)

Characteristics of several of the new nonglass ion-selective electrodes and of several reference electrodes were studied in detail with particular emphasis upon the nitrate ion-selective electrode. A new high accuracy standard addition technique for the potentiometric determination of nitrate ion in a cell without liquid junction using the fluoride electrode as a reference was developed. This method eliminates the liquid junction and dilution and activity coefficient changes cancel. The method is applicable to all monovalent anions for which an electrode is available and enables the determination of anion concentrations to within 1% relative accuracy. Low temperature potentiometric titrations of perchlorate and tetrafluoroborate ions with tetraphenylarsonium chloride and ion-selective electrodes were investigated and found to give high accuracy and reasonably good sensitivity for these ions. The nitrate electrode was used to follow nitrate ion concentration in microbial cultures. It was found to be useful for following nitrate ion reductions in situ.

Keywords: water, analysis, analytical techniques, nitrates, electrodes, ions, fluorides, microbiology, bacteria, volumetric analysis, water chemistry, pollutant identification, monitoring, ion-selective electrodes, standard addition, and potentiometry.

DIGITAL SYSTEMS FOR ON-SITE DATA COLLECTIONS FOR WATER QUALITY ANALYSIS

Arkansas University, Fayetteville, Water Resources Research Center
M. K. Testerman
Available from NTIS as PB-197 116, $3.00 in paper copy, $0.95 in microfiche. Arkansas Water Resources Research Center, Publication No. 8, Fayetteville (1970)

A prototype system has been developed for recording and transmitting digital data at a remote water quality monitoring station in an unattended manner. As many as eight analog signals from transducers, which measure water quality characteristics such as dissolved oxygen, temperature, pH, chlorides, conductivity, ORP, and turbidity, are converted to digital signals and recorded in binary coded decimal format on magnetic tape. This unit may be contacted from a central station for playback of the day's recording. The transmitted data can be recorded at the central station by teletype. Each data record includes a time-of-day "word" so that all data is identifiable. The techniques developed during this contract period have possible application in many areas of water resource research, particularly for use in making water quality measurements in remote areas or at numerous sites report to one central station.

Keywords: data processing, design criteria, digital computers, electronic equipment, on-site data collection, monitoring, data transmission, data collections, water quality, analytical techniques, and instrumentation.

ION-SELECTIVE ELECTRODES—THEORY AND APPLICATIONS IN WATER ANALYSIS

Pittsburgh University, Pennsylvania Graduate School of Public Health
B. Andelman
Water Pollution Control Federation, Vol. 40, No. 11, Part I, pages 1844—1860 (Nov. 1968)

Recently, several electrodes for such ions as fluoride, nitrate, sulfide, sodium, potassium, calcium, and total hardness (divalent ions) have become commercially available. The potentials measured by these electrodes, which sense activity rather than concentration, are influenced to varying extents by the presence of ions other than those whose measurements are desired. The relationships of these effects to the measured potentials are discussed, as are techniques for interpretation in terms of ion concentrations, rather than activities. Among the advantages of these electrodes for water analysis are their speed and their potential for in situ monitoring of ions in natural and treated waters. Some applications of these electrodes for water analysis are discussed, including comparisons between their analyses and those obtained by other techniques.

Keywords: electrodes, ions, water analysis, analytical techniques, alkali metals, chemical potential, phosphates, nitrates, sulfates, halides, copper, magnesium, calcium, instrumentation, hardness (water), water chemistry, ion-selective electrodes, activity, activity coefficient, and concentration.

MODERN MONITORING OF A TREATED INDUSTRIAL EFFLUENT

Proctor and Gamble Company, Cincinnati, Ohio, Ivorydale Technical Center
R. G. Ostendorf

J Water Pollution Control Federation, Vol. 41, No. 1, pages 89—98 (Jan. 1969)

The wastes monitoring system is described installed by the Charmin Paper Products Company at their waste treatment facility. BOD wastes are evaporated and then incinerated, and fiber-bearing wastes are treated for suspended solids removal by screening, precoat filters, and dissolved air flotation. The wastes monitoring system used to maintain the DO in the Susquehanna River at the prescribed 5.0 mg/l concentration consists of composite sampler, pH recorder, DO and BOD analysis, and continuously indicating suspended solids and total carbon equipment. The total carbon and suspended solids analyzers are described.

Keywords: monitoring, biochemical oxygen demand, dissolved oxygen, industrial wastes, wastewater, evaporation, incineration, filtration, flotation, total carbon, suspended solids, Susquehanna River, pH, paper wastes, screening, and composite sampler.

AUTOMATIC METHODS FOR THE ANALYSIS OF NATURAL WATERS

Wisconsin University, Madison, Water Chemistry Lab.
G. F. Lee

Proceedings of International Biological Program Symposium held in Amsterdam and Nieuwersluis, Netherlands (October 10—16, 1966). Chemical Environment in the Aquatic Habitat, G. L. Colterman and R. S. Clymo (Editors), N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam, pages 169—180 (1967)

Water pollution monitoring and limnochemical research programs often require chemical analyses of large numbers of samples. Automated procedures for colorimetry and electrometry have been used and offer even greater promise for the future. In a typical colorimetric application, the Technicon Auto Analyzer, key development of which is a reliable proportionating pump and assemblages of various modules, makes possible analyses involving diverse manipulations including distillation, solvent extraction, dialysis, and precipitation. The possibility of replacing colorimeters with other detectors (flame photometer, atomic adsorption spectrophotometer, continuous flow fluorometer) ensures greater flexibility. A table of 40 water analyses which have been automated includes procedures diverse as alkyl benzene sulfonates, chemical oxygen demand, plant nutrients, and various vitamins and enzymes. Example of an automated phosphate analysis is described in detail. Automated procedures may permit greater precision and, due to careful control of conditions at each step, may allow use of reactions which do not proceed to completion. Automatic and semi-automatic titrations are also effective. The paper describes a European example of titrimetry which permits nine separate analyses. Future developments in automation will include self-contained monitoring stations for collection of limnological data. A list of American equipment manufacturers is included.

Keywords: chemical analysis, water chemistry, instrumentation, alkylbenzene sulfonates, colorimetry, volumetric analysis, limnology, monitoring, water pollution, water quality, phosphates, chlorides, bicarbonates, carbonates, hydrogen ion concentration, calcium, magnesium, chemical oxygen demand, dissolved oxygen, sulfates, organic acids, flame photometry, fluorometry, nutrients, vitamins, and enzymes.

USER TRIALS OF A SUBMERSIBLE WATER QUALITY RECORDING METER

Ontario Water Resources Commission, Toronto
M. D. Palmer
Ontario Water Resources Commission, Great Lakes Survey Program (1969)

Two submersible recording water quality meters were field-tested in the Great Lakes for accuracy and stability. These meters are battery operated and completely self-contained in a sealed stainless steel tube 16.5 cm in diameter by 76.2 cm long, weighing 21 kilograms. Temperature, pressure, real time, turbidity, pH, conductivity and dissolved oxygen are automatically evaluated every five minutes to one hour and recorded on magnetic tape. The information can also be transmitted to the water surface via line for telemetering. The meters have proven to be both flexible and reliable in water quality monitoring and model development programs.

Keywords: water quality, monitoring, instrumentation, water pressure, water temperature, hydrogen ion concentration, turbidity, conductivity, dissolved oxygen, and water quality meters.

ON TARGET WITH ON-LINE

Calgon Corp., Pittsburgh, Pa.
E. D. Neuberger
Industrial Research, 12, 11, pages 42—45 (Nov. 1970)

On-line analyzers developed for water monitoring and control have been successfully modified and applied to various industrial processes. Continuous sampling and analysis provide measurements for automatic process controls to satisfy a variety of industrial plant needs. The use of sodium ion electrodes in on-stream analyzers has been modified to meet exacting requirements. This technology has also been applied to air pollution control. The sodium electrode method was shown to be effective in monitoring stack gases and this led to the development of the Stack Gas Sniffer Sampling System. Other on-stream analyzers for industrial processes provide sampling and measurement based on differential conductivity. Operations and applications of different systems are described.

Keywords: analytical instrumentation, automatic control, industrial plants, ion-selective electrodes, monitoring systems, and ion-stream analyzers.

WATER QUALITY MONITORING SYSTEMS

R. J. Hensley
Industrial Water and Pollution Control Conference and Advanced Water Conference, 22nd and 23rd Proceedings held in Stillwater, Oklahoma (March 29—30, 1971). Sponsored by Oklahoma State University, University Extension, Stillwater (1971)

The Corps of Engineers, Tulsa, Oklahoma, has been working on control of natural chloride pollution of the Arkansas and Red River Basins for several years. The objective of the study was to determine methods and means of improving and managing water quality in the basins. Some of the benefits and problems of using sophisticated equipment to monitor the water quality of groundwater are discussed.

Keywords: salts, water quality control, ground water, chlorides, rivers, monitoring systems, and brine emissions.

RECENT ADVANCES IN WATER QUALITY MONITORING

R. Briggs and K. V. Melbourne
J Society Water Treatment Examination, 17, pages 107—120 (1968)

The authors discuss existing instrumentation for monitoring water quality, and describe two submersible systems recently developed for use in rivers and estuaries, and the principles of operation of commercial nitrate, fluoride, and enzyme electrodes. The development of an instrument for the continuous recording of ammonia in river water and effluents in which the sample is acidified, stripped of carbon dioxide and air with helium, followed by the quantitative oxidation of ammonia to nitrogen and measurement of nitrogen concentration by a diffusion katharometer, is described. The design of a battery-operated instrument for monitoring organic matter, based on the absorption of ultraviolet light, is also described.

Keywords: water quality monitoring, rivers, nitrate, fluoride, enzyme, and continuous monitors.

NATIONAL SYMPOSIUM ON DATA AND INSTRUMENTATION FOR WATER QUALITY MANAGEMENT

J. E. Kerrigan (Editor)
Water Resources Center, Hydraulics and Sanitary Lab, University of Wisconsin, Madison, Wis. 53706, Price $5.00. Proceedings of the National Symposium on Data and Instrumentation for Water Quality Management, Conference of State Sanitary Engineers and Wisconsin University (July 21—23, 1970)

The National Symposium on Data and Instrumentation for Water Quality Management was held at the University of Wisconsin in Madison, Wisconsin, on July 21-23, 1970, under the joint sponsorship of the Conference of State Sanitary Engineers and the Wisconsin Water Resources Center, with sixteen professional societies as co-sponsors. The central theme of the 43 papers in the Symposium was to assess the benefits offered by advanced data collection, analysis and display systems toward the enhancement of the nation's environment.

Keywords: data processing, data collections, data storage and retrieval, water quality control, conferences, water pollution control, monitoring, hydrologic data, flood forecasting, digital computers, systems analysis, simulation analysis, computer programs, and water quality data.

APPLICATION OF AUTOMATIC SAMPLING TO TODAY'S WATER QUALITY CONTROL PROGRAMS

Gurnham and Associates, Inc., Chicago, Ill.
F. C. Gurnham and M. I. Beach
Proceedings, Ontario Industrial Waste Conference, 17th, Niagara Falls, Ontario, pages 109—118 (June 7—10, 1970)

The following variables must be considered in the selection of automatic sampling equipment: 1) accessibility of sampling site, 2) general character of the wastes, 3) flow patterns, and 4) analyses to be performed. To accommodate the preceding variables, there are six main types of samples, namely: 1) individual or "grab", 2) simple composite, 3) sequential composite, 4) continuous, 5) hand-proportioned composite, and 6) automatic-proportioned composite. Sampling equipment ranges in price from a few dollars to several thousand dollars, and in size from the portable to the permanent models. A brief description of the various samplers includes vacuum or compression samplers, fixed volume and scoop samplers, cup or bucket elevator samplers, and pump samplers. The important service provided by a sampling schedule must include production of a sample of adequate size, provision for its preservation, and provision for containment until analyses can be performed. Growing concern with environmental pollution has caused much interest in monitoring pollutional parameters, but without a representative sample, all analyses performed are merely wasted. Therefore, specification, installation, and operation of automatic sampling devices must be considered a critical part of any waste survey.

Keywords: sampling, automatic control, analytical techniques, analysis, monitoring, dissolved oxygen, temperature, flowmeters, pumps, weirs, water pollution control, hydrogen ion concentration, pump sampler, scoop sampler, and vacuum sampler.

NEW APPLICATIONS OF ON-STREAM ANALYSERS IN PULP MILLS

Calgon Corp., Pittsburgh, Pa.
H. M. Rivers and E.D. Neuberger
Technical Association of the Pulp and Paper Industry, Vol. 53, No. 7, pages 1250—1254 (July 1970)

On-stream analyzers developed in recent years for industrial water monitoring and control have been successfully modified and applied to certain specific needs in pulp mills. Automatic titration systems are being used to analyze for acid or alkali content in pulp mill waste or process streams and for chlorine residuals in bleach plant operations. Sodium content in recovery furnace stack gas is being accurately (0.1 ppm) and reliably determined by a selective ion electrode. Differential conductivity analyzers are reliably and accurately determining the effective alkali in kraft process black liquor due to special sample handling facilities and a unique means of neutralizing these samples. The applications of on-stream sampling devices are reviewed with emphasis on their value as pollution abatement, quality control, plant economics and research devices. By providing an abundance of reliable information about plant processes, automatic on-stream analyzers afford many opportunities for effecting improvements in pulping operations.

Keywords: pulp and paper industry, automatic control, measurement, acidity, alkalinity, conductivity, chlorine, ions, water analysis, monitoring, pollutant identification, sampling, pulp wastes, industrial wastes, analytical techniques, and on-stream analysis.

AUTOMATED WATER QUALITY MONITORING

D. G. Ballinger
Environmental Science Technology 2, pages 606—610 (1968)

The author, in an illustrated article, surveys some of the types of instruments currently used for water quality monitoring and discusses their design, performance, scope, and some problems encountered in use.

Keywords: instruments, water quality, ion-selective electrodes, wet chemistry analyzers, TOC, and TOD.

COMPREHENSIVE INSTRUMENTATION SYSTEM FOR SIMULTANEOUS MONITORING FOR MULTIPLE CHEMICAL PARAMETERS IN A MUNICIPAL ACTIVATED SLUDGE PLANT

Roy F. Weston, Inc., West Chester, Pa.
V. T. Stack; N. S. Zaleiko, Jr.; F. L. Doll; W. F. Milbury
Water Quality Instrum., 1, Pages 151— 165 (Eng) (1972)

A continuous automatic monitoring and sampling system is described, and 6 months of operation has verified the feasibility of the system. Although most Technicon Auto Analyzer systems require more development before being applied as low-maintenance stable and rugged industrial monitoring systems, Auto Analyzers of orthophosphate and NH_3-N indicated that they would be effective as long-term monitors. The total C analyzer system utilized as a part of the sample monitoring analyzing capability, demonstrated reasonable application to waste treatment plant monitoring. Dissolved O_2, pH, and turbidity monitoring devices are at satisfactory levels of developing for immediate use in activated sludge treatment plant monitoring systems. The value of immediate assessment of critical operating parameters is important for maintaining optimum performance of a wastewater treatment plant and for making meaningful operational changes for variations in inlet wastewater concentrations.

Keywords: monitoring, DO, pH, turbidity, municipal and wastewater.

INSTRUMENTATION FOR ENVIRONMENTAL MONITORING WATER

Environmental Instrumentation Group, Lawrence Berkeley Lab. University of California, Berkeley CA 94720 LBL-1, Vol. 2 (1973)

A comprehensive survey of instrumentation for environmental monitoring is being carried out by the Lawrence Berkeley Laboratory under a grant from the National Science Foundation. Instruments being investigated are those useful for measurements in air quality, water quality, radiation, and biomedicine related to environmental research and monitoring. Consideration is given to instruments and techniques presently in use and to those developed for other purposes but having possible applications to this work. The results of the survey are given as: (a) descriptions of the physical and operating characteristics of available instruments, (b) critical comparisons among instrumentation methods, and (c) recommendations of promising methodology and development of new instrumentation. The survey material will be compiled in four looseleaf volumes that can be periodically updated.

Keywords: instruments, monitors, metals, halides, cyanides, nitrogen, phosphorous, sulfur, biological parameters, pesticides, phenols, petrochemicals, grease and oil, and physical parameters.

MEASUREMENTS OF THE INTENSITY OF FLOW AND LEVEL OF SEWAGE AND SEDIMENTATION IN A MODERN SEWAGE TREATMENT PLANT

Polish Association of Sanitary Engineering and Technology, Warsaw
Jerzy Komorek
Gaz Woda Tech Sanit. 44(9): pages 300—304 (1970)

These measurements met with difficulties due to the very variable composition of sewage containing fats, soap, oils, hair, rags, cotton, and other suspensions showing a variable degree of dispersion. Methods are presented for measuring the level of sewage and intensity of flow, which gave very good results.

Keywords: cotton-D, fats, flow, hair, intensity, measurements, oil, plant, rags, sedimentation, sewage, soap, and treatment.

WASTEWATER VOLUME TO BE MEASURED ULTRASONICALLY

Anon
Instrumentation Technology, 18(5): pages 14 and 25 (May 1971)

The Sewage Treatment Commission of the City of Milwaukee has launched a pollution control project implementing ultrasonic devices in metering the volume of wastewater entering its treatment plants. Partially funded by a grant from the Environmental Protection Agency, the demonstration project will extend over a 15-month period and will try to find a relatively low-cost system that can be installed on existing sewer lines. The metering system, designed by Badger Meter Manufacturing Co., includes an ultrasonic flowmeter in each sewer for measuring the velocity of wastewater, an ultrasonic level instrument of the in-air sonar type for each sewer that will measure the level of wastewater, electronic gear for processing signals, and recording instruments to provide charts of the volume flow.

Keywords: sewage treatment plants, instruments, volume-metering system, and ultrasonic devices.

AN AUTOMATIC OUTFLOW MEASURING DEVICE

Commonwealth Scientific and Industrial Research Organization, Deniliquin (Australia), Riverina Lab.
M. L. Sharma and R. A. Bawden
Water Resources Research, Vol. 7, No. 2, pages 429—431 (April 1971)

A device for continuous and accurate measurement of very small quantities and slow rates of water flow is described. Drops of uniform size are formed and counted instantaneously by digital counters as the drops fall between pairs of electrodes. The counts and time are recorded by automatically photographing the counters and a clock at suitable time intervals.

Keywords: flow measurement, flowmeters, discharge (water), instrumentation, lysimeters, data collections, flow rates, gages, and flowmeter (automatic).

SEWER FLOW MEASUREMENT IN A LARGE INDUSTRIAL PLANT

Polymer Corp., Sarina (Ontario)
D. D. Livingstone
Proceedings, Ontario Industrial Waste Conference, 15th, pages 146—156 (June 9—12, 1968)

For accurate design of new pollution control facilities, and more accurate measurement of the actual performance of the treatment facilities, a survey scheme was developed in 1967 to measure all important discharges and identify the sources of these streams. The allowable error was 10%. A description of the plant and treatment facilities (with a plan layout) is given. A recommended eight-point survey plan is outlined. The measurement equipment used in this survey was the portable type, at a cost of less than $500. The Doll flow tube, current meter, pilot tube, bucket and stopwatch (the bucket was used for the settling basin), and salt dilution methods gave the required results within the allowable error and at a low cost.

Keywords: treatment facilities, survey, measurement, sewers, flow rate, velocity, costs, sedimentation basin, and current meter.

PRACTICAL METHODS FOR DETERMINING SEWAGE FLOW FOR ALL COMMUNITIES

Metropolitan Corp. of Greater Winnipeg (Manitoba)
R. M. Girling
Water and Sewage Works, Vol. 116, No. 7, pages 250—258 (July 1969)

Measurement of sewage flow rate has become an important aspect in practical sanitary engineering. Starting from the basic concepts of flow-measuring devices, the reasons for the measurement of sewage flow rate are enumerated. Various methods of measurement and the corresponding measuring devices are briefly explained, with particular reference to sewage measurement. The circumstances under which a particular type of measuring device is used are explained. The limitations, possible errors while using, and the advantages of each type of measuring device are briefly presented. A method for measuring flow rate at sewage pumping stations is also given. Problems are worked out to illustrate the application of various devices.

Keywords: instrumentation, industrial wastes, sampling, design criteria, corrosion, manholes, stilling well, radioactive isotopes, average flow, Parshall flume, municipal sewage system, regulators, and plumb bob.

REPORT ON TRAPEZOIDAL FLUME MODEL

Los Angeles County Flood Control District, Calif.
Prepared for U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, 29 pages, 19 illus. (March 1963)

Following the San Dimas Canyon (Johnstone Peak) fire of 1960, the U.S. Forest Service established a comprehensive research project with an experimental forest, one phase of which was to obtain and evaluate hydrologic data relative to runoff and debris movement from burned watersheds. A preliminary step undertaken in this aspect of the research project was the construction and installation of 36 flumes of trapezoidal section in selected watersheds ranging between 2 and 101 acres in size. On the basis of observations made during storm runoff periods and analysis of hydrologic data obtained during the 1961–1962 storm season, the Forest Service concluded that hydraulic model tests of field installations should be undertaken. In view of the value of hydrologic data from recently burned watersheds, the Los Angeles County Flood Control District joined with the Forest Service in conducting model flume tests. The report describes the model study and presents rating curves to relate flow rate and stage recorded by water-level recorders. These rating curves are intended for general application to all flumes where velocity immediately upstream from the inlet is less than critical velocity in the flume, and where the flume is free from the effects from downstream flow stage, but are considered indicative only where the flow contains appreciable debris quantities. In addition, criteria are presented for modification of flume installations to effect a control at flume inlets where such control does not already exist.

Keywords: model studies, demonstration watersheds, forest fires, debris avalanches, surface runoff, flumes, canyons, forest management, hydraulic models, hydraulic engineering, Froude's number, and trapezoidal flumes.

THE LE ACOUSTIC FLOWMETER—AN APPLICATION TO DISCHARGE MEASUREMENT

C.R. Hastings

J. Water Works Assoc., Vol. 84, No. 2, pages 127–151 (June 1970)

A variety of discharge measurement devices has been invented of which a flow-measuring system using the LE flowmeter is the most recent system to substantially advance the art. The concept employed is an application of numerical integration by Gaussian Quadrature. Test results under varying conditions of fully developed and distorted flow show that this measurement system has an rms accuracy better than 1.0 percent. Use of the LE acoustic flowmeter gives this flow-measuring system features not possessed by other devices, such as linearity, bidirectionality, no head loss, and no need for calibration.

Keywords: flowmeters, discharge measurement, hydraulics, instrumentation, and testing.

PORTABLE RECORDING OF SEWER FLOW

Swann, W.M.

Water Wastes Eng., Vol. 6, No. 12, page 12 (Dec. 1969)

In the region including Toronto, sewer flows were measured in order to assess problems arising from storm flows and infiltration into sanitary sewers. It was found that poor manhole hydraulics in one or two manholes can reduce the capacities of large sewer systems. Continued observation and control of methods by which the surface water enters sanitary sewers were recommended.

Keywords: storm runoff, manholes, sewerage, hydrology, sewer hydraulics, sanitary sewers, and surface flow.

VELOCITY MEASUREMENTS IN SEWERS VITAL TO DESIGN AND MAINTENANCE

Lamont W. Curtis
Water Sewage Works, Vol. 116, No. 4, pages 144—147 (April 1969)

Discharges can be converted to wastewater volumes per capita in a sanitary sewer, or can be related to rainfall in a storm sewer. The velocity, depth, and slopes measured can be used to compute Manning's coefficient of the roughness-friction factor. The salt-concentration method of measuring velocity was best suited for developing a discharge-depth relationship for a number of sewers, as well as giving an indication of the sewer condition. The equation applicable for the salt-concentration method is $Q=AV$, where Q is the discharge; A is the area, computed from the measurement of the flow depth; and V is the velocity measurement. The equipment needed, procedure, analyses of data, and continuous gaging methods are discussed in detail. It is concluded that there is no ratio that, when applied to surface velocity measurements, will give accurate average velocities in a pipe. Results of the studies indicate, however, that a ratio of 0.75 will give a good approximation for flow depths between 0.2 and 0.4 of the pipe diameter.

Keywords: flow measurement, sewers, analysis, methodology, velocity, Manning's equation, and sewer hydraulics.

APPLICATION OF AN ACOUSTIC STREAMFLOW-MEASURING SYSTEM ON THE COLUMBIA RIVER AT THE DALLES, OREGON

Geological Survey, Menlo Park, Calif.
Winchell Smith
Water Resources Bulletin, Vol. 7, No. 1, pages 69—78 (Feb. 1971)

To collect accurate, independent records of flow on the Columbia River at The Dalles, Oregon, an acoustic streamflow-measuring system was installed. This device measures the velocity of flow by the difference in travel times of acoustic pulses transmitted through the water in each direction along a diagonal path across the river. The flow of water along the path increases the speed of one signal and retards the speed of the other. The difference in time of travel is related linearly to the water velocity along the path. Installation of the system, which is the first application of an acoustic flowmeter in a large natural channel, was completed in April 1969. It has been in continuous operation since that date. The velocity index and water-surface elevation are used as a two-variable index in the computation of flow. These variables, correlated against current-meter measurements made by use of specialized boat equipment, provide a reliable basis for computations of instantaneous and daily mean discharges.

Keywords: flowmeters, stream gages, discharge measurement, open-channel flow, gaging stations, velocity, acoustics, instrumentation, current meters, discharge (water), streamflow, and flowmeters (acoustic).

FLOW METERS FOR WATER RESOURCE MANAGEMENT

Agricultural Research Service, Phoenix, Ariz.
J.A. Replogle
Water Resources Bulletin, Vol. 6, No. 3, pages 345—374 (May—June 1970)

Regulated water flow is an essential feature of modern civilization. Effective use of water resources by industrial, agricultural, and municipal processes and as domestic conveniences requires controlled-flow systems. Closely related to this regulation is the requirement for flow measurement, the techniques of which have developed over many centuries. Because of the relatively long history of flowmetering and the multitude of improvements and new developments, a complete coverage of the subject is not possible. In this paper, greater emphasis is placed on describing new developments and less conventional methods that are most usable for water-resource applications and research studies, and less emphasis on older, generally familiar devices. Because of the diverse requirements in water measurement, few devices can be regarded as having no possible application. Selecting the most usable devices is somewhat arbitrary, but passing mention is made of most known devices for all fluids. Reference material for more complete coverage of a particular device or system is also included.

Keywords: flow measurement, fluid flow, flowmeters, measuring instruments, rotating meters, volumetric meters, metering, weirs, sharp-crested weirs, reviews, rectangular weirs, Cipolletti weirs, and Parshall flumes.

CONTROL EXPERIENCES AND STRATEGIES

Because of diurnal and seasonal variations in wastewater flow rates and strength, municipal treatment plants operate under widely varying loadings and thus produce a variable quality effluent. Moreover, disturbances such as storm events, oil, grease or industrial chemical dumps contribute to upsets commonly experienced in wastewater treatment facilities. To minimize these deleterious effects, most treatment processes utilize high-capacity, self-regulating processes that may unnecessarily increase capital and operating costs. Without the benefits of process control, major failures such as bulking, biomass washout and digester souring occur all too frequently. It is generally recognized that thoughtful applications of automatic process control can improve the operation, maintenance, efficiency, productivity, and reliability of most wastewater treatment facilities.

An ideal control system should accomplish the desired objective without any error; however, in general this is not possible because of limited control action. All that one can expect is to accomplish desired tasks with minimum error. The goals of wastewater treatment plant automation are as follows:

- Improve treatment reliability
- Reduce operating and maintenance costs
- Minimize effluent variability
- Detect problems and institute corrective measures
- Reduce equipment and structure sizes through increased productivity
- Find control actions that are readily adaptable by new and existing treatment plants
- Devise stable control systems.

Undoubtedly very few control schemes could simultaneously satisfy all of the above goals, but with good engineering judgement, the best mix of controller goals should guide the design engineer.

Typical process control systems' components are:

- Process type itself
- Measuring devices, sensors, flow-measuring devices, and automatic analytical devices
- Manipulation variables for adapting process conditions to load and ambient disturbances
- Transmission devices for carrying the instrument signals
- Controller logic to implement strategy
- Final control elements for executing the control strategy.

The forthcoming control experiences and strategies literature search concentrates on the process behavior with respect to load and ambient changes, controller logic, and the selection of manipulation variables. Instruments were covered in the previous section. The other items, final control elements and transmitters, are more appropriately discussed in equipment catalogs of the major instrument and hardware manufacturers.

This search represents a collection of abstracts summarizing technical articles related to the automation of wastewater treatment facilities and closely related chemical processes. The search included most recognized environment and automatic control periodicals, symposium series, and conference proceedings published from 1969 to 1973.

The following guidelines directed the selection of the technical articles during the control strategy and experience phase of the literature search:

- Articles that describe the basic cause-and-effect relationships (equations of state) for the commonly employed wastewater treatment processes.
- Case studies and field evaluations of automatic control in germane situations. These articles are concerned with local automatic control, central control, and direct digital control of wastewater treatment plants, wet weather facilities, collection systems, and pertinent chemical processes.
- Follow-up articles that demonstrate the transition from automatic control theory to practice. Articles that promulgate impractical mathematical techniques were avoided.
- Automation review articles.

Since the degree of automation practiced in most wastewater treatment plants has been traditionally low, the principle objective of this literature search was to provide a concise reference of background information, control philosophies, and experimental projects conducted by leading municipalities. As the case studies demonstrate the benefits of automatic control, process control will in time become an integral part of most wastewater treatment plants.

TERTIARY TREATMENT OF SECONDARY INDUSTRIAL EFFLUENTS BY ACTIVATED CARBON

Texas University, Austin
N.K. Burleson, W.W. Eckenfelder, Jr. and J. F. Malina, Jr.
Proceedings of the Industrial Waste Conference, 23rd, pages 474—483 (1968)

Effluents from laboratory and plant scale activated sludge reactors were filtered through Whatman Number 42 filter paper. The effluents were from treatment of two refinery and one petrochemical wastes and had COD values and TOC values respectively of 86 and 23 mg/1, 40 and 16 mg/1; and 107 and 33 mg/1, for refinery waste number one. Refinery waste number 2 and the petrochemical waste, respectively. Various amounts of activated carbon from the same source but of two different mesh sizes were added to the wastes and agitated for contact times up to 320 hours. While the smaller mesh size exhibited a higher rate of adsorption in the early stages of the tests the removal after 320 hours of contact time was essentially the same. Data indicate that: the bulk of adsorption took place in the first 100 hours of contact time; that activated carbon will remove up to 85% of refractory material expressed as TOC from secondary industrial effluents; and the Freundlich isotherm successfully described the absorption process in the batch studies. Activated carbon columns were used to treat waste containing 2, 4 dichlorophenol and concentration time profiles from each column recorded.

Keywords: activated carbon, tertiary treatment, industrial wastes, chemical oxygen demand, adsorption, activated sludge waste treatment langmuir isotherm, total organic carbon, refinery waste, petro chemical waste, and refractory materials.

COLLECTION, CHARACTERIZATION, AND STUDY OF BIODEGRADABILITY AND CHEMICAL OXIDATION OF CARBON-ABSORBED MATERIALS FROM EFFLUENTS FROM SEWAGE TREATMENT PLANTS

Iowa State University, Ames, Dept of Civil Engineering
R. I. Johnson
Eng Res Inst., Final Report 96 pages (Dec 1968)

Organic materials found in sewage treatment plant effluents were adsorbed on activated carbon filters. The adsorbed material, after solution and concentration from the activated carbon, was fractionated according to solubility. Attempts were made to identify and characterize the organic materials, but the task was almost impossible. Most fractions were capable of further biodegradation as well as chemical oxidation when in the more concentrated form. A new tertiary or secondary biological treatment process of Pulsating Adsorption Beds (PAB) was developed using the adsorption phenomena as a concentration effect to enhance biodegradability. The process showed removals of 80 to 90% of the soluble organic carbon in a synthetic sewage at 125 million gallons per acre per day hydraulic loading and 265 pounds BOD per thousand cubic foot per day organic loading.

Keywords: adsorption, biological treatment, effluents, similitude.

OPTIMIZATION OF THE REGENERATION PROCEDURE FOR GRANULAR ACTIVATED CARBON

MSA Research Corporation, Evans City, Pa

Copy available from GPO Sup Doc as EP2.10:17020 DAO (7/70) $1.25; microfiche from NTIS as PB-208 205, $0.95. Environmental Protection Agency Water Pollution Control Research Series, 115 pages (July 1970)

Laboratory scale experiments were conducted on the regeneration of activated carbons spent in tertiary treatment of wastewater. Wet spent carbon being regenerated thermally undergoes three regeneration stages: (1) drying at about 220 deg F; (2) pyrolysis of the adsorbed pollutants at 500 to 1550 deg F; and (3) activation with flue gas and steam at 1600 to 1700 deg F. Data indicated that alkaline and iron oxide ash accumulation catalyze the oxidation of carbon pores in the 18 A to 28 A diameter range, the pores most effective in pollutant adsorption. Leaching with HCL was found to remove the metallic elements and allow regeneration to proceed with less destruction of the carbon. Other observations included: (1) steam as activating gas is more efficient than CO2 in recovery of the initial properties of the carbon; (2) slow drying of the wet carbon is more effective than fast drying; (3) the true loss of 1.8% of the carbon volume in thermal regeneration appears to proceed by generation of sub micron-sized fines rather than carbon oxidation; and (4) attempted chemical regeneration without heat was ineffective and/or uneconomical.

Keywords: activated carbon, adsorption, separation techniques, chemical reactions, catalysts, oxidation, metals, leaching, steam, wastewater treatment, optimization, thermal regeneration, chemical regeneration, adsorptive capacity, and pyrolysis.

PLANT SCALE REACTIVATION AND REUSE OF CARBON IN WASTEWATER RECLAMATION

Neptune Microfloc, Inc., Corvallis, Oregon
G. Culp and A. Slechta
Water and Sewage Works, Vol. 113, No. 11, pages 425—431, (Nov 1966)

At the 2.5 MGD tertiary sewage treatment plant at South Lake Tahoe, activated carbon has been very effective in removing organic materials. Efficient regeneration of the carbon is provided. For each MG of effluent about 740 lbs of carbon is removed through a 2 inch pipeline to two spent carbon tanks (coal-tar epoxy coating) with screened drain for dewatering the carbon to 43 percent moisture in 1 hour. Carbon is moved by a variable speed stainless steel screw conveyor, capacity 40 to 250 lbs/hour, discharging into the top of the regeneration furnace. The carbon moves downward through the six hearths each equipped with gas-air control burners. Steam can be added also. The regenerated carbon is discharged from the bottom of the furnace into a quench tank, from which it is pumped to the regenerated carbon storage tank, where it is washed to remove any fine carbon. Regeneration is controlled by hourly determination of the apparent density of the carbon—it decreases with destruction of the absorbed organics to a final apparent density of 0.49. Ash content is also monitored. Carbon loss has averaged less than 10 percent per regeneration cycle. Cost to regenerate and make up one pound of carbon was only one-sixth the cost of virgin carbon. Regeneration costs are only 3.8 cents per one thousand gallons of effluent.

ACTIVATED CARBON ADSORPTION

Keywords: water treatment, sanitary engineering, activated carbon, costs, waste water treatment, carbon, treatment facilities, California, carbon regeneration, and Tahoe (Calif).

EFFECTS OF SUSPENDED SOLIDS CONCENTRATIONS ON THE STRUCTURE OF TURBULENCE AND THE OXYGEN TRANSFER MECHANISM IN ACTIVATED SLUDGE

Tokyo University (Japan), Department of Urban and Sanitary Engineering
T. Matsuo
Preprint, presented at 6th International Water Pollution Research Conference, Session 8, Paper No. 15, 14 pages (June 21, 1972)

A laboratory-scale aeration tank of 35 liter capacity was used to determine the types of flow regions obtained in activated sludge systems and to determine the effects of bubble size and suspended solids concentration on both the turbulence regime and the oxygen transfer characteristics. Initial results demonstrated that turbulence affected by suspended solids is in the "microscale," compared to the size of the solids; the effects of suspended solids on "macroturbulance" patterns were not distinctly identified. However, further investigations demonstrated that the scale of turbulance having a direct effect upon "KLA" or the oxygen uptake rate is also the "microscale." Because of the limitation of the measuring instruments, however, a complete quantitative analysis of turbulence is not yet possible, but the shape, size, or concentration of suspended solids may be considered in obtaining a qualitative measure in order to characterize the structure of turbulence. For these reasons, in further testing, the concentration of suspended solids as well as the intensity of mixing must be accounted for to maintain biologically similar conditions.

Keywords: turbulence, mass transfer, oxygenation, reaeration, activated sludge, aeration, bubbles, suspended solids, particle size, sludge, mixing, biodegradation, instrumentation, laboratory tests, wastewater treatment, and oxygen uptake rate.

LONGITUDINAL MIXING IN SPIRAL FLOW AERATION TANKS

McMaster University, Hamilton (Ontario)
K. L. Murphy and B. I. Boyko
Journal Sanitary Engineering Division, ASCE, Vol. 96, No. SA2, pages 211—221 (April 1970)

Rhodamine B tracer was introduced as a pulse into an aeration tank 270 ft long, 27 ft wide, and 15 ft deep. Tracer concentration was monitored in the effluent. Tests were performed using water from Hamilton Bay. An analysis of the tracer output curves indicated that the dispersion model described the longitudinal mixing in the tank. The dispersion coefficient was found to be independent of detention time in the range tested (4.8 to 13.3 hr). A correlation was determined between the dispersion coefficient and airflow rate in the range tested (6.4 scfm to 25.3 scfm per 1000 cubic ft of tank volume). Both fine and coarse bubble diffusers indicated the same correlation. An analysis of data from tanks of various geometry indicated a correlation between the ratio of the dispersion coefficient and square of the tank width to the airflow rate. For a tank of conventional width and airflow rates of 15 scfm to 20 scfm per 1000 cubic ft of tank volume, the dispersion coefficient should range between 2000 and 8000 sq ft/hr. The degree of mixing that exists in aerators with conventional air rates is such that they tend to approach fully mixed conditions.

Keywords: dispersion, tracers, activated sludge, aeration, sewage treatment, plug flow, airflow, and detention time.

AERATION CONTROL

DISSOLVED OXYGEN CONTROL IN ACTIVATED SLUDGE

Pacific Engineering Lab., San Francisco, Calif.
R.A. Ryder
Proceedings, Industrial Waste Conference, 24th, pages 238—253 (May 6, 7, and 8, 1969)

Development of electrochemical sensing elements for dissolved oxygen measurement has enabled dissolved oxygen levels in wastewater treatment plant aeration tanks to come under the realm of automatic control. A typical DO control system consists of: (1) a DO sensor, (2) DO amplifier, (3) DO recorder and automatic controller, (4) aeration air input controller, and (5) controlled element such as a blower of turbine speed, throttled air valve, or turbine submergence. Associated benefits of DO control include: (1) avoidance of over or under-aeration and corresponding cost savings; and (2) continuous response to changing oxygen demands caused by variations in flow, waste strength, temperature, barometric pressure, and biological requirements of the mixed liquor. Dissolved oxygen levels can be maintained at plus or minus 0.2 mg/l from a set point. During sludge bulking, adjustment of the DO to 0.75 mg/l will suppress filamentous organisms causing the bulking. Skimming of secondary/ sedimentation tanks and addition of polyelectrolytes to improve settling of bulking sludges are also recommended to improve treatment efficiency.

Keywords: dissolved oxygen, activated sludge, automatic control, electrodes, sampling, temperature, pressure, organic loadings, chlorination, protozoa, bacteria, flocculation, electrolytes, sedimentation, biochemical oxygen demand, wastewater treatment, laboratory tests, bulking, filamentous bacteria, and polyelectrolytes.

POSSIBILITIES IN MEASURING AND OPERATIONAL TECHNIQUES FOR THE AUTOMATIC CONTROL OF OXYGEN SUPPLY IN AERATION TANK

G. Rincke and U. Moller
Vom Wass., 34, pages 297—333 (1968)

For maximal efficiency in the activated sludge process, automatic control of the oxygen supply is necessary. The authors review existing methods and instruments for the continuous measurement of oxygen and give useful hints based on practical experience on the construction and operation of instrument and control panels.

Keywords: dissolved oxygen, automatic control, and continuous monitoring.

THE INFLUENCE OF SUSPENDED SOLIDS ON THE RATE OF OXYGEN TRANSFER IN AQUEOUS SOLUTIONS

G.T.M. Kroon
Proc. 4th Int. Conf. Wat. Pollut. Res., Prague, pages 219—229 and pages 231—239 (1969)

Using a specially designed apparatus, which is described and illustrated, experiments were carried out to determine the rate of oxygen transfer in samples of artificial mixed liquor from a bench-scale activated sludge plant and in suspensions of aluminum hydroxide (made to resemble the biological mass in size, settling properties, and tendency to agglomerate on agitation, but lacking respiration), and results were compared with those for tap water under the same operating conditions. Compared with tap water, the solubility of oxygen, expressed as the oxygen saturation value, was reduced by less than 5 per cent in mixed liquor or a suspension of aluminum hydroxide. The rate of transfer of oxygen in both suspensions was greater than that in tap water and, particularly at low rates of aeration, decreased when the concentration of suspended solids increased. The rate of decrease depended on the quality of the suspended flocs. In the mixed liquor the rate of oxygen transfer was independent of the rate of respiration and was unaffected by the metabolic products. In discussion, theoretical consideration is given to the effect of suspended solids on the solubility of oxygen and the hydrodynamics of the aqueous phase, and of the liquid surface. The effect of "reactive" solids on oxygen transfer is also discussed.

Keywords: oxygen, transfer, solids, respiration rate, and hydrodynamics.

OXYGENATION IN AERATION TANKS

J.J. Suschka
Wat. Pollut. Control Fed., 43, pages 81—92 (1971)

Graphic results are given of pilot-scale experiments on 4 different types of aeration tank to determine the correlation between the efficiency of oxygen absorption and the vectorial velocity of the air bubbles. It was found that although the velocity of the water in the aeration tank has an important effect on oxygen absorption the relationship is complex; in some ranges of air-flow rates, the oxygen absorption efficiency increases with decreasing velocity of water, while in other ranges of air-flow rates it increases with increasing water velocity. Further studies showed that at constant mixing rate an increase in the observed turbulence rate results in increasing oxygenation. It appears that for effective aeration it is necessary to achieve a high degree of mixing and to keep the average velocity of the ascending bubbles in the low range.

Keywords: oxygenation, velocity, turbulence, mixing, and bubbles.

EFFECT OF TEMPERATURE ON OXYGEN TRANSFER IN WATER

Windsor Univ. (Ontario)
J.K. Bewtra, W.R. Nicholas and L.B. Polkowski
Water Research, Vol. 4, pages 115—123 (August 19, 1969)

Several investigators have studied the effect of temperature on oxygen transfer but in each of those experiments one or more of the test conditions did not represent common aeration practices. In this study the tests were made in a full-scale aeration tank section with different types of aeration devices arranged similar to arrangements in common practice. Both saran tubes and spargers were used as the diffusion media. The airflow rate ranged between 7 and 32 ft 3/min/ft of tank length, and the water temperature range was 10-30 deg C with measurements taken in 2.5 deg C increments. Samples were analyzed by the Winkler method for dissolved oxygen and the rate of oxygen absorption was computed by a mathematical procedure described previously be Morgan and Bewtra (1960). The percent oxygen absorptions at zero dissolved oxygen concentration, obtained for various airflows and temperatures, were plotted for both types of diffusers. Final results of the tests were statistically analyzed and summarized in a mathematical expression.

Keywords: aeration, oxygenation, absorption, dissolved oxygen, temperature, oxidation lagoons, waste water treatment, spiral flow aeration tank, partial pressure, regression coefficients and oxygen transfer.

THE ROLE OF AERATION IN THE ACTIVATED SLUDGE PROCESS

Hydraulic Research Inst., Prague (Czechoslovakia)
V. Zahrandka
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 53—69 (1966)

The combination of factors known as the aeration space activity is the new basis for activated sludge design work. Activated sludge dry weight, where the food to microorganisms ratio does not approach the state of non-flocculent growth, is unable to represent the purification capacity of an activated sludge tank reactor. The aeration space activity can be determined by an experiment in which all process parameters must be applied in full scale, including the mixing factor. In most cases, the mixing factor influences the aerated space activity to a much greater extent than does the sludge loading factor. As long as high oxygenation capacity is required, then the power requirements are not significantly different for the several types of aerators, and consequently, the power requirement is not a determining factor in the aeration system design.

Keywords: turbulence, mixing, nutrients, flocculation, coagulation, sedimentation, water purification, activated sludge, sludge, sludge treatment, waste water treatment, aeration, aerated space activity, floc morphology, food to microorganisms ratio, mechanical suppressor, filamentous sludge, and oxidation rate.

AERATION CONTROL

DISCUSSION OF THE ROLE OF AERATION IN THE ACTIVATED SLUDGE PROCESS

Technische Hochschule, Vienna (Austria)
W. Von Der Emde
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 79—81 (1966)

The 'specific aeration intensity' introduced by Zahradka allows several different aeration devices with different immersion depths to be easily compared. While it is possible to get better oxygenation efficiencies at higher aeration intensities, this is not always the case. To achieve an effluent quality of 25 mg/l BOD_5, the oxygenation capacity should range from 2-3 Kg 0_2/day/cubic meter, and 3-5 Kg 0_2/day/cubic meter for partial treatment. Table I shows average values obtained from a series of tests at Hamburg 1964-1965. At present, there is no common denominator for comparison of wideband and furrow aeration with surface aerators. The energy input related to one cubic meter of aeration tank for one hour is proposed as such a yardstick. Turbulence should be considered as a factor along with but not totally in place of aeration time and sludge loading factors. While turbulence is a significant factor, it is of no greater importance than the conventionally accepted parameters.

Keywords: oxygenation, turbulence, mixing, aeration, biochemical oxygen demand, activated sludge, waste water treatment, specific aeration intensity, immersion depth, inka-aeration, and bubble-aeration.

FORMAL DISCUSSION OF THE ROLE OF AERATION IN THE ACTIVATED SLUDGE PROCESS

Department of the Seine, Paris (France), Sanitary Services
M. Feuillade
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 69—72 (1966)

Despite much research on the subject, the proponents of small bubble aeration are still in disagreement with the proponents of large bubble aeration as to which bubble size is actually optimal for activated sludge. Experiments conducted at the Purification Plants of the City of Paris, the Department of the Seine, the Experimental Center at Colombes, and the Purification Plant of Acheres support the coarse or medium bubble system as providing the greatest overall benefit for the activated sludge system. The differences in aeration efficiencies between large and small bubbles become smaller as the oxygenation capacity becomes larger. Also, larger bubbles break up the growth patterns of filamentous organisms, while at the same time providing the best use of the aeration power for flocculating the sludge blanket and settling organic substances on the sludge. The Beckman electrode was used to obtain values of dissolved oxygen present in a sample of activated sludge. This equipment is correct only within 10%, and the most economical design will not be possible until oxygen levels at all points in the tank at all times can be continuously monitored.

Keywords: aeration, oxygenation, turbulence, metabolism, microorganism, biodegradation, dissolved oxygen, biochemical oxygen demand, activated sludge, waste water treatment, respiratory activity, oxygen capacity, specific intensity, purification efficiencies and sludge liquor.

AUTOMATIC CONTROL OF THE AMOUNT OF DISSOLVED OXYGEN IN WASTE WATER

D.N. Smirnov, A.A. Kuz'min and R.N. Saifi
Vodosnab, sanit. Tekh., 1969. No. 5, pages 18—21 (1969), Chem. Abstr., 71, No. 22, 267 (1969)

In a polarographic apparatus used to control the concentration of dissolved oxygen in wastewaters, under laboratory or industrial conditions, the probe comprises an electrolyte of 0.1 N sodium acetate with agar-agar, between solid electrodes of gold and zinc, protected by gas-permeable membranes. Diffusion of oxygen through the membrane causes depolarization of the indicating electrode and flow of current in the electrical circuit.

Keywords: dissolved oxygen, automatic control, diffusion, wastewater and DO control.

MODULATION OF THE OXYGEN SUPPLY IN AN ACTIVATED SLUDGE PROCESS

Degremont S.A., Malmaison (France)
J. Bernard and R. Louboutin
Fifth International Water Pollution Research Conference, San Francisco, Preprint, Paper II-6 (July 26—August 1, 1970)

Oxygen supply systems should be designed to take into account the following facts: (1) variation of the liquid level in the aeration tanks, (2) variation of the number of tanks in use, (3) variation in time, temporarily or permanently, of the nominal head-loss of the air diffusion devices, (4) variation in the pressure conditions and ambient air temperature, (5) variation in number of air-generating units in use. The influence of these various parameters differ according to the sources of oxygenation employed. The positive displacement air blowers, centrifugal blowers, and mechanical surface aerators are discussed with this in mind. The ability to vary rotary blowers to modulated rotary blowers by the use of multispeed motors, make-up air compressors and continuous speed variation is discussed. The modulation of centrifugal air blowers is discussed from the standpoint of insertion of local head-losses, modification of the inlet aerodynamic conditions of the blowers, electrical moter speed control, and adjusting both speed and inlet conditions of the blower. Modulation of surface aerators is also discussed.

Keywords: oxygenation, activated sludge, irritation, sewage treatment, waste water treatment, biological treatment, efficiencies, performance, modulation, blowers, and surface aerators.

THE INFLUENCE OF SUSPENDED SOLIDS ON THE RATE OF OXYGEN TRANSFER IN AQUEOUS SOLUTIONS

G.T.M. Van der Kroon
Water Research, Vol. 2, No. 1 pages 26—30 (Jan. 1968)

The relationship between dissolved oxygen content and the rate of respiration of microorganisms was studied in a mixed liquor from activated sludge plants and in Rotterdam tap water. The experimental apparatus allowed for a constant rate of gas flow and injection of oxygen when its partial pressure in the gas decreased. The oxygenation capacity and maximum rate of oxygen absorption were measured and the ratio between them was plotted against suspended solids concentration. It was concluded that the suspended solids concentration played an important role in the oxygen transfer in various solutions. The properties of clay and aluminum sulfate suspensions resembled those of a mixed liquor with respect to oxygen transfer.

Keywords: dissolved oxygen, oxygenation, respiration, suspended load, solid wastes, dissolved oxygen analyzers, waste assimilative capacity, activated sludge, gases, microorganisms, clays, laboratory tests, oxygen transfer and sludge liquor.

MECHANISM OF INTERFERENCE OF SURFACE ACTIVE AGENTS IN AERATION SYSTEMS

Michigan Univ., Ann Arbor and Clemson Univ., S.C.
K.H. Mancy and W.E. Barlage, Jr.
Advance in Water Quality Improvement (Editors: E.F. Gloyna and W.W. Eckenfelder, Jr.), Austin, Texas, Univ. of Texas Press, pages 262—286, (1968)

Continued attention has been given to the effects of water soluble surface active agents (SAA) on aeration processes. All experiments to date have encountered certain conflicting results which indicate that the presence of SAA in aeration systems may affect greatly the hydrodynamics of the air-water interface and, therefore, the rate of gas transfer. The physicochemical characteristics of the air-water interface have been examined closely in various systems including bubble aeration, stream aeration, surface aeration in stirred vessels, and liquid laminar jet systems. In comparing the results from these three different aeration systems, better understanding has been gained of the mechanism of interface of SAA on gas transfer. The degree of reduction of gas transfer rates caused by SAA in aeration systems depends on the hydrodynamics of the contactor and the chemical properties of the given SAA. There are two types of SAA interferences with gas transfer (depending on the structure and physicochemical properties of the SAA): (1) The SAA adsorbed film covers partially or totally the water surface, blocks dissolution sites at the interface, or distorts intermolecular forces between the gas molecule and the water surface necessary in the dissolution process. (2) The SAA increases the water surface viscosity, suppresses the interface hydrodynamic activity, and forms a viscous subsurface hydration layer.

Keywords: aeration, interfaces, surfactants, physicochemical properties, films, testing, gases, adsorption, hydrodynamics, mass transfer, aerosols, Reynolds number, mixing, bubble aeration, stream aeration, surface aeration, liquid laminar jet system, gas transfer, surface active agents, interfacial resistance, dynamic surface tension, dynamic surface concentration, and oxygen transfer coefficient.

AERATION DEVELOPMENTS IN EUROPE

Technische Hochschule, Vienna (Austria)
W. Von der Emde
Advances in Water Quality Improvement (Editors: E.F. Gloyna and W.W. Eckenfelder, Jr.), Austin, Texas, University of Texas Press, pages 237—261 (1968)

Before the construction of large sewage treatment plants in Austria, investigations were made of major treatment facilities involving large scale aeration processes in Essen, Hamburg and Munich, Germany. The performance and economics of major aeration systems are discussed. The Essen plant tested the oxygenation efficiencies of Saran-tube, plastic-box and Brandol-tube aerators under various arrangements as to location and bubble size. Results of the Danjes fine bubble aeration system at Munich are furnished. Results of widespread use of Simplex cone aeration throughout Europe are summarized. Major differences between the Simcar cone aeration system and the Vortair cone system are noted. Special operational and power requirements of the BSK turbine aeration system is noted. Modifications to aerators and rotors leading to the development of the Mammut rotor are explained showing effects of immersion depth on absorbed energy aeration efficiency, and oxygen capacity. Comparisons are made with the Haworth paddle aeration system and the Kessener brush aeration system.

Keywords: aeration, diffusion, oxygenation, absorption, efficiencies, energy, sewage treatment, bubbles, design, detergents, baffles circulation, design data, Danjes system, cone aeration, Saran-tube aerator, Brandol-tube aerator, plastic-box aerator, Germany, Simplex cone, oxygen absorption, Europe, Munich, Essen, Hamburg, Simcar cone, Vortair cone, and BSK turbine.

JET AERATION IN ACTIVATED SLUDGE SYSTEMS

Houdaille Industries, Inc., Prophetstown, Ill., and Iowa Univ., Ames
R.W. West, and W.L. Paulson

Journal of the Water Pollution Control Federation, Vol. 41, No. 10, pages 1726—1736 (Oct. 1969)

A jet development program and system design study that extends the original work from particular operating conditions to the full spectrum of fluid flow, submergence, and system design are described. Jet aerator performance was analyzed under standard test conditions and the oxygen absorption values per unit of power input were found to be in range similar to other types of aerator devices. It was shown that with optimum liquid flow rate, aeration efficiency improved with decreasing air flow rates. Jet aerator systems provide complete mixing of aeration basin contents and can easily be adopted to automated control of air flow rates for optimum system performance. Guidelines are recommended for selection of aeration system components. A typical layout is presented to illustrate system design for optimum performance in activated sludge wastewater treatment units.

Keywords: activated sludge, aeration, costs, efficiency, mass transfer, submergence, wastewater treatment, sewage treatment, jet aeration, system design, aerator submergence, waste treatment basin and piping distribution.

NEW CONCEPTS IN OXYGEN TRANSFER AND AERATION

Texas Univ., Austin
W.W. Eckenfelder and D.L. Ford

Advance in Water Quality Improvement (Editors: E.F. Gloyna and W.W. Eckenfleder Jr.), Austin, Texas, University of Texas Press, pages 215—236 (1968)

AERATION CONTROL

A general review is made of recent concepts in oxygen transfer and the practical data for design of aeration equipment is summarized. The theory and general development of the mechanism of oxygen transfer under quiescent and turbulent conditions are discussed. The most significant factors influencing the important overall transfer coefficient and the liquid film coefficient are temperature, surface active agents in the liquid, and mixing intensity. Empirical mathematical expressions are presented for the temperature effect and for the film of excess surface concentration of surfactant molecules which serves as a barrier to diffusion. The effects of various mixing intensity ratios on oxygen transfer rates under various aeration systems and flow regimes are shown graphically. The most commonly accepted techniques used to determine aeration equipment performance efficiency and capabilities are: (1) nonsteady state aeration of deoxygenated water, (2) steady-state and nonsteady state aeration of activated sludge, and (3) steady-state aeration of tap water. Aeration equipment used for sewage and industrial waste treatment consists of air diffusion units, turbine aeration systems in which air is released below the rotating blades of an impeller, and surface aeration units in which oxygen transfer occurs by virtue of high surface turbulence and liquid sprays.

Keywords: aeration, oxygen, transfer, diffusion, mixing, surfactants, temperature, equations, design data, mass transfer, activated sludge, equipment (aeration), bubbles (aeration), turbulence, overall transfer coefficient, liquid film coefficient, mass transfer coefficients, oxygen transfer efficiency, deoxygenated water, steady-state aeration, nonsteady-state aeration, mixing intensity, surface active agents, diffused aeration and turbine aeration.

OXYGEN DEMAND AND SUPPLY IN AN ACTIVATED SLUDGE PLANT

Michigan State Univ., East Lansing, Dept. of Civil Engineering
K.L. Schulze and R.D. Kooistra
Journal of the Water Pollution Control Federation, Vol. 41, No. 10, pages 1763—1774 (October 1969)

Mixed liquor oxygen consumption rates, r sub r, specific oxygen consumption rates, K, and BOD of primary effluent were measured during the fall and summer academic terms at the first bay of a three-bay activated sludge aeration tank series. Hourly and daily fluctuations in both r sub r and K sub r were quite similar to fluctuations in BOD. The similarity of fluctuations of r sub r and K sub r indicated that changes in r sub r essentially were caused by changes in the physiological activity of the floc and not simply changes in mixed liquor suspended solids concentration. While oxygen uptake rates of 9 mg/l/hr to 42 mg/l/hr and 32 mg/l/hr to 90 mg/l/hr were observed during the summer and fall respectively, aeration equipment was found capable of providing dissolved oxygen at a rate of 22.5 mg/l/hr. Thus the aeration equipment acted as a limiting factor and slowed down the process. It is concluded that for a relatively inflexible and low rate oxygen supply, as provided by most aeration equipment, it would be advantageous to strive for complete mixing conditions.

Keywords: activated sludge, oxygen requirements, aeration, biochemical oxygen demand, sewage treatment, dissolved oxygen, wastewater treatment and oxygen uptake rates.

DISCUSSION—INVESTIGATION OF BENEFITS FROM AUTOMATIC CONTROL OF DISSOLVED OXYGEN IN THE AERATION CHANNELS OF A LARGE ACTIVATED SLUDGE PLANT ACHIEVING FULL NITRIFICATION

A. B. Wheatland

Water Research Vol. 6, pages 455 and 456 (1972)

Investigations conducted at the Rye Mead 2.4 MGD sewage purification works in England demonstrated that activated sludge reactors operating under dissolved oxygen (DO) control used 22% less air than uncontrolled reactors during 6-month parallel tests. For the control aeration vessel, signals from four Mackereth-type DO probes automatically regulated airflow to the diffusers so that the mixed liquor DO could be maintained at 2.0 mg/L. At times the DO exceeded 2.0 mg/L in the controlled aeration vessel because a minimum airflow was needed to prevent diffuser blockage. Both reactors produced high-quality fully nitrified effluents. Generalities concerning the installation, operation, and economies of DO control are discussed.

Keywords: dissolved oxygen, automatic control, and airflow.

AMMONIA STRIPPING AT WASHINGTON, D. C.

Robert A. Taft Water Research Center, Cincinnati, Ohio. Advanced Waste Treatment Research Lab.
T. P. O'Farrell and F. P. Frauson
Proceedings, Pittsburg Sanitary Engineering Conference, 8th, Pittsburg, Pennsylvania, pages 251—263 (Feb. 1970)

An ammonia stripping system, consisting of 5 towers, each packed with 40, 4 ft x 5 ft x 1/2 inch grids, was subjected to a 75 day test. The efficiencies of ammonia removal were determined at various air to liquid (G/L) rates. Liquid loadings were restricted to 1 gpm/ft squared due to the fan capacity. The data was combined to formulate an empirical curve which indicated that 500 ft cubed of air per liquid gallon is required for 90% ammonia removal. Temperatures averaged 78F and 77F for inlet air and water respectively, and pH ranged from 11.8 to 12.0. Accumulation of calcium carbonate in the system forced intermittent shutdown of the system for maintenance. Air to liquid rates decreased from an initial 350 ft cubed air/gallon of liquid to a final 250 ft cubed air/gallon of liquid, thus decreasing the efficiency of the system for ammonia removal, also on account of calcium carbonate buildup in the towers. A 20% system efficiency decrease toward the end was attributed to falling temperatures. Total scale accumulation in the towers was 2 tons, with each grid requiring manual cleaning. Removal of the CaCO3 also upset the chemical clarifier system. From these tests it was determined that scale deposition and reduced temperatures for part of the year preclude ammonia stripping as a feasible nitrogen removal mechanism in Washington, D. C.

Keywords: cooling towers, ammonia, temperature, scaling, calcium carbonate, chemical precipitation, lime, aeration, biochemical oxygen demand, flocculation, nitrification, alkalinity, hydrogen ion concentration, phosphorus, tertiary treatment, waste water treatment, District of Columbia, and ammonia stripping.

REMOVAL OF AMMONIA BY SELECTIVE ION EXCHANGE

Robert A. Taft Water Research Center, Cincinnati, Ohio. Advanced Waste Treatment Research Lab.
R. B. Dean
Proceedings, Pittsburg Sanitary Engineering Conference, 8, Pittsburg, Pennsylvania, pages 233—238 (Feb. 1970)

Zeolites have been developed which are selective for ammonia. At a given fraction of NH..4 in solution, the fraction of NH..4 on the ion exchange material is much higher for the Hector clinoptilolite than for the conventional ion exchange resin, IR 120. Ammonium ion-specific zeolites are poor adsorbents for Ca ions, and therefore can be regenerated with limewater. Ca ions replace ammonium ions on the resin, and the high pH produces un-ionized NH3 from the NH..4 ions. Sodium ions present in the solution act to speed up the regeneration. Limewater regenerant can be stripped of ammonia in packed columns or cooling towers, since volumes are 5% or less of the total flow, the water can be settled to remove calcium carbonate, replenished with lime, and re-used. There is no waste brine. Cost of ammonia removal by non-selective resins is estimated at 8.1 cent/1000 gallons, with the cost of brine disposal not included. Cost for selective zeolites are reported as between 3 and 6 cent/1000 gallons, with no brines to be disposed of, when treating 15-20 mg/1 NH4-N.

Keywords: ammonia, ion exchange, zeolites, selectivity, resins, nitrogen, temperature, hydrogen ion concentration, lime, adsorption, calcium carbonate, cooling towers, brines, regenerant and stripping.

NITROGEN REMOVAL BY BREAKPOINT CHLORINATION

Robert A. Taft Water Research Center, Cincinnati, Ohio. Advanced Waste Treatment Research Lab.
D. F. Bishop and T. A. Pressley
Proceedings, Pittsburg Sanitary Engineering Conference, 8, Pittsburg, Pennsylvania, pages 239—247 (Feb. 1970)

Ammonia oxidation by 'breakpoint' chlorination provides a physical-chemical means for removing ammonia and completing the natural nitrogen cycle (i.e., oxidation of the ammonia to N2). Chlorine is added to the ammonia water until chlorine residual has reached a minimum and ammonia nitrogen has entirely disappeared. This method has been used for many years in the water industry and has been found to be pH dependent, with efficient breakpointing occurring only at pH 7-8.5. In natural water, non-ammonia chlorine demand may call for a chlorine to ammonia-nitrogen weight ratio of 15 to 1 or greater. Disadvantages of the method include: (1) satisfactory nitrogen removals may not be achieved if greater than 1 mg/l of permanent residual nitrogen compounds occur such as NO3-; (2) large chlorine doses produce more acid by chlorine hydrolysis than can be neutralized by most waste waters, necessitating the addition of caustic to maintain a favorable pH range; (3) high chlorine demands require increased supplies of stored chlorine which represent a potentially hazardous condition; and (4) at chlorine costs of $0.50/lb and a 200 mg/l dose, the cost for the chlorine alone is 8.3 cents/1000 gallons. However, if pilot plant studies establish that acceptable removals can be obtained, on-site chlorine generation from bines, which produces both chlorine and caustic, may overcome the caustic and storage problems in large plants. The operation simplicity alone recommends the method for small plants.

Keywords: chlorination, ammonia, nitrogen, oxidation, nitrogen cycle, hydrogen ion concentration, hydrolysis, neutralization, alkalinity, acids, pilot plants, cost analysis, storage, nitrates, waste water treatment, breakpoint chlorination, chloramines, chlorine residual, and caustic.

NITROGEN REMOVAL FROM WASTE WATERS

Federal Water Quality Administration, Cincinnati, Ohio. Advanced Waste Treatment Research Lab.
Dean, R. B.
Available from the National Technical Information Service as PB-206 306, $3.00 in paper copy, $0.95 in microfiche. Federal Water Quality Administration Report, 24 pages (May 1970)

AMMONIA REMOVAL

The various forms in which nitrogen occurs in wastewater, and the equally varied methods used to remove these nitrogen compounds have been the subject of this progress report. The seven papers included provide first a brief review of some possible deleterious effects of nitrogen in the nation's wastewaters in the form of nitrites, nitrates, ammonia, ammonium ion, or dissolved nitrogen gas. Methods of removal which were studied included: (1) suspended growth biological reactors; (2) packed column biological reactors; (3) removal of ammonia nitrogen by air stripping; (4) removal of ammonia nitrogen by ion exchange; (5) removal of nitrates by ion exchange; and (6) miscellaneous other methods for removing various nitrogenous compounds.

Keywords: nitrogen, separation techniques, waste water treatment, ammonia, nitrates, nitrites, amino acids, biodegradation, nitrification, denitrification, ion exchange, chlorination, oxidation, cost analysis, technical feasibility, and economic feasibility.

SIMULATION OF AMMONIA STRIPPING FROM WASTE WATER

Environmental Protection Agency, Cincinnati, Ohio. Water Quality Office
J. F. Roesler, R. Smith and R. G. Eilers
Journal of the Sanitary Engineering Division, ASCE, Vol. 97, SA 3, Proc Paper 8182, pages 269—286 (June 1971)

A computer program that can be used for the design and simulation of ammonia stripping and film packed cooling towers was described. The ammonia stripping portion of the program was embedded in the cooling tower circulation in order that the variation of Henry's Law constant with water temperature could be taken into account. The logic of the program was arranged for: (1) design of cooling towers, and (2) design of ammonia stripping towers with temperature correction. Two tower configurations were included in the program: (1) Countercurrent in which the liquid flows down and the air moves upward; and (2) Cross current in which the liquid flows down and the air moves horizontally at right angles to the flow of the liquid. Regression equations relating the height of a transfer unit and gas and liquid flow rates were developed from pilot and full scale plant data. Detailed capital and operating cost data were taken from the literature. The computed results indicated that for a crossflow tower an optimum gas to liquid ratio is about 1.75, and for counterflow the optimum is at about 4. Relations between the height of the tower percent removal, cost and influent flow were also examined. It was shown that the total treatment cost levels off between 7 mgd and 10 mgd.

Keywords: cooling towers, sanitary engineering, sewage treatment, computers, cost analysis, reclamation, water temperature, waste water treatment, ammonia stripping, and Henry's law.

AMMONIA NITROGEN REMOVAL BY STRIPPING WITH AIR

Federal Water Quality Administration, Cincinnati, Ohio. Advanced Waste Treatment Research Lab.
J. B. Farrell
In: Nitrogen Removal from Wastewaters, Paper No. 4, 3 pages FWQA Project 17010—05/70 (May 1970)

AMMONIA REMOVAL

Ammonia can be desorbed or stripped from solution by raising the pH of the solution to the point where the ammonium ion is converted to dissolved ammonia, and contacting the solution with ammonia free air. Municipal wastewater normally contains 15 to 25 mg/l of ammonium ion which is removable by stripping, but the volume of air required is nearly 400 cu. ft./gallon of wastewater in a counter current-flow packed tower. Pressure drop across a packed tower is one psi, and since power is proportional to the product of pressure drop and volumetric flow rate, power costs were prohibitive. Development of a slat filled tower in lieu of a packed tower halved the pressure drop and so reduced power costs at Lake Tahoe, where 90% removal efficiencies were then obtained in a 24 ft. high counter current tower. Problems with ammonia stripping include the increased solubility of ammonia in cold water making winter operation more costly. Scaling problems have also occurred in several of the locations now using the process, although the scale did not adhere to the tower in South Africa. Cost has been estimated at 2.9 cent/1000 gallons of wastewater treated exclusive of the cost of lime and facilities to raise the pH to 11.0. In colder weather, costs will increase sharply. An operating pH of 10.5 counter current operation rather than crossflow, and an openfill to allow easy flushing of accumulated solids will help to control scale in the tower.

Keywords: ammonia, solubility, separation techniques, temperature, freezing, chemical precipitation, sludge, calcium carbonate, cost analysis, waste water treatment, desorption, stripping, and pressure drop.

NITROGEN REMOVAL IN SEWAGE TREATMENT PROCESS

Eidgenoessiche Anstalt fuer Wasserversorgung, Abwasserreinigung und Gewaesserschutz, Zurich (Switzerland)
K. Wuhrmann
Verh Int Ver Limnol, Vol XV, pages 580—596 (Feb. 1964)

Nitrogenous compounds derived from sewage probably play a significant role in eutrophication and nitrate-enrichment of groundwaters, although detailed knowledge of their involvement is still forthcoming. The author has reviewed nitrogen removal by conventional treatment processes. Land disposal, pond treatment, and biological oxidation, in trickling filters or with activated sludge, remove not more than 50% of total nitrogen from waste water, percentages ineffective in preventing enrichment of receiving waters. Over 90% removal has been achieved with physico-chemical processes of ion exchange and ammonia stripping at high pH, methods which are presently uneconomical. Microbial denitrification may be a practical technique of nitrogen elimination. Already occurring during conventional biological treatment, denitrification can be optimized to achieve 90% elimination from sewage. The author describes technical scale experiments which easily achieved highly reliable denitrification. In these experiments, final effluents after treatment of domestic sewage (total nitrogen after preliminary sedimentation, 25-30 ppm) contained 2-4 ppm. Attainment of complete anaerobiosis during an extra detention step was essential for such removal. Subsequent phosphorus precipitation yielded an effluent with 1-2 ppm total nitrogen. The report contains record of brief floor discussions relative to phosphate removal, characteristics of denitrifying flora, sulfate reduction, and nitrogen fixation by cyanophytes.

AMMONIA REMOVAL

Keywords: eutrophication, water pollution control, water pollution sources, nitrogen compounds, sewage treatment, water quality, tertiary treatment, percolation, trickling filters, activated sludge, cycling nutrients, denitrification, nitrogen cycle, sewage effluents, microbiology, phosphorus compounds, pseudomonas, nitrogen fixation, sewage lagoons, sewage bacteria, sulfur compounds, and groundwater.

STEADY-STATE MODEL FOR ACTIVATED SLUDGE WITH CONSTANT RECYCLE SLUDGE CONCENTRATION

M. Ramanathan and A. F. Gaudy
Biotechnol. Bioengng, 13, pages 125—145 (1971)

In connection with pilot-plant studies on the continuous culture of heterogeneous microbial populations in the activated-sludge process (see Wat. Pollut. Abstr., 1970, 43, Abstr. No. 121), equations have been developed and computational analysis carried out to show the effect on substrate and cell concentrations in the reactor of the sludge recirculation ratio, dilution rate, feed concentration, cell yield and growth rate constant. It was shown that a constant concentration of cells in the recirculation of sludge produced a steady-state system.

Keywords: mathematical model, monod kinetics, and return activated sludge.

AUTOMATIC CONTROL OF AN ACTIVATED SLUDGE REACTOR

H. E. Klei
Connecticut Univ., Storrs FWQA-17050-EVF-02/71, PB-211 334 PC$3.00/MF$0.95 24 pages W72-12795 (Feb. 11, 1971)

A feed forward control scheme was constructed and demonstrated on an activated sludge reactor using as feed the primary effluent from a municipal treatment plant. The control scheme can be used to control both the air and recycle solids rates to the reactor to compensate for the increased carbon level in the feed stream. At normal detention times an improvement in process efficiency was observed with the control scheme.

Keywords: automatic control, activated sludge feed forward, and return activated sludge.

RESPONSE OF BIOLOGICAL WASTE-TREATMENT SYSTEMS TO CHANGES IN SALT CONCENTRATIONS

D. F. Kincannon and A. F. Gaudy
Biotechnol. Bioengng, 10, pages 483—496 (1968)

Following previous experiments on the effect of high salt concentrations on batch-operated activated-sludge units (see Wat. Pollut. Abstr., 1966, 39, Abstrs. Nos. 1942 and 1943; and 1968, 41, Abstr. No. 828), the effect of changes in salt concentration on continuous-flow activated-sludge units treating synthetic waste water was investigated. While the salt concentration was being increased to 30,000 mg per litre, high efficiency in the removal of substrate was not maintained, but after an acclimation period the efficiency recovered. Upon diluting the salt out of the system, a significant rise in cell yield was noted as the salt level passed through the range 8000—10,000 mg per litre. Steady operation at a salt concentration of 8000 mg per litre sustained the cell yield at a high level. The effects of slug doses of 30,000 mg of sodium chloride per litre were investigated in batch systems, using sludge from different stages of the continuous-flow system.

Keywords: activated sludge, salt, acclimation and efficiency.

THE EFFECT OF CELL RE-CYCLE ON ACTIVATED SLUDGE PROCESS OPERATION

California Univ., Davis. Dept. of Civil Engineering
E.D. Schroeder
Water Research, Vol. 5, No. 1, pages 29—39 (Jan. 1971)

Conventionally designed activated sludge processes are currently operating in a range bounded by ideal plug flow and ideal stirred tanks, with completely mixed systems approaching the ideal stirred tanks in operational characteristics. In all cases, trade-offs occur between growth rate (and corresponding bio-oxidation rate), recycle ratio, and recycle cell concentration. Recycle cell concentration increases result in increases in reactor cell concentration, for a given recycle ratio, and also a decrease in the residence time necessary to remove a given amount of organic material. The necessity for high recycle cell concentrations establishes the importance of the secondary clarifier to the system. On a general basis, usage of low secondary clarifier overflow rates would probably mean fewer operational difficulties with the activated sludge process. The most important factor directly concerned with recycle, however, is that recycle and cell concentration ratios directly influence the observed growth rate which alters the actual kinetic processes. The effect of recycle must therefore be included in field data in order for such data to be reliable.

Keywords: activated sludge, kinetics, biodegradation, mixing, aeration, organic loading, analytical techniques, mathematical models, waste water treatment, biological treatment, cytological studies, recycle cell concentration, plug flow, and residence time.

STUDIES ON THE RESPONSE OF ACTIVATED SLUDGE TO SHOCK-LOADINGS

A. F. Gaudy and P. Krishnan
Proc. 12th Ont. ind. Waste Conf., pages 43—47 (1965)

Some results are given from studies on the effect of shock loads on activated-sludge systems (see also Wat. Pollut. Abstr., 1966, 39, Abstr. No. 1133), including the phenomenon of sequential substrate removal and its causative mechanism. The observations are discussed in relation to the kinetics of the activated-sludge process under shock and non-shock loading conditions. It is also concluded that at least a portion of the refractory compounds remaining in the final effluent from biological-treatment plants may be compounds not originally present in the waste but produced by the cells from a portion of the original carbon source.

Keywords: shock loading, response, mechanism, activated sludge, and kinetics.

COMMON USE OF CONVENTIONAL ACTIVATED SLUDGE

DNA AND NITROGEN RELATIONSHIPS IN BULKING ACTIVATED SLUDGE

E. J. Genetelli
J. Wat. Pollut. Control Fed., Res. Suppl., 39, pages R32–R44 (1967)

Sludge loading ratio is frequently used to control the performance of the activated-sludge process, but this is not entirely satisfactory since the amount of suspended solids is not necessarily related to the total enzymatic activity of the system, and laboratory experiments have, therefore, been carried out to investigate the feasibility of using either the deoxyribonucleic acid (DNA) content or the nitrogen content as a basis of organic loading parameters. The results, summarized in tables and graphs, indicated that a loading parameter for activated sludge may be based on lb of BOD fed daily per lb of DNA in the aeration tank, and that this is more sensitive than the conventional loading parameter based on volatile suspended solids as an index of organism concentration. The DNA content of activated sludge was found to be related to both the number and type of organism present. The loading parameter based on DNA content was more generally applicable to different substrates than one based on nitrogen; the latter was found to be adequate for a system fed with glucose but not for a system fed with casein hydrolysate. A change in the sludge population to a predominantly Sphaerotilus mass, and a decrease in DNA content, were found to occur just before an increase in sludge volume index, and before there was any actual indication of serious sludge bulking, and this is considered to confirm the causal relation between the development of Sphaerotilus and sludge bulking. On the basis of these experiments, some studies were carried out at several sewage works, and the field data confirmed the usefulness of DNA content as an index of activated-sludge performance.

Keywords: loading, MLVSS, DNA index, bulking and performance.

EFFECT OF DISSOLVED OXYGEN AND SUBSTRATE CONCENTRATION ON THE UPTAKE RATE OF MICROBIAL SUSPENSIONS

A. A. J. Kalinske
Wat. Pollut. Control Fed., 43, pages 73–80 (1971)

The author outlines the basic processes involved in the activated-sludge process and discusses how a knowledge of these processes can be used to establish the relations between the various factors affecting the process, with a view to assisting in the economic design of activated-sludge plants. Microbiological studies have shown that the respiration rate of dispersed cells is not affected by dissolved-oxygen concentration over the range 0·5 to 35 mg per litre. Controlled agitation to produce an adequate degree of micro-turbulence is necessary to obtain the maximal transfer rates of oxygen and substrate to the cell surfaces; recently developed mechanical surface aerators provide an economical way of introducing oxygen into solution and also produce the necessary degree of micro-turbulence. Increasing the concentration of dissolved oxygen by the use of pure oxygen or oxygen-enriched air is not considered to have any advantages over mechanical aeration.

Keywords: dissolved oxygen, activated sludge and efficiency.

LINEAR SUBSTRATE REMOVAL IN THE ACTIVATED SLUDGE PROCESS

Texas Univ., Austin
L. F. Tischler and W.W. Eckenfelder, Jr.
Advances in Water Pollution Research, Proceedings, Fourth International Conference on Water Pollution Research, Prague, (April 21–25, 1969), London, Pergamon Press, pages 361–384 (1969)

Removal of mixtures of various simple organic compounds was investigated using mixed biological cultures in an effort to predict the kinetics of the activated sludge process. The simple organic compounds glucose, phenol, and analine were all removed linearly (zero order) by an activated sludge acclimated to a mixture of the compounds. Variation of the initial concentration of each compound had no effect on the removal rate of the compound by a given sludge. The removal rates of the compounds in a unit containing a mixture of the three, were the same as the rates found when each compound was tested alone. This indicates that different types of organisms may be responsible for the removal of each simple substrate. The predominant type of microorganism present in the continuous activated sludge unit was determined by the organic loading level on the unit. A filamentous sludge, found at higher loadings, was capable of assimilating glucose and phenol at significantly greater rates per unit biological solids than the flocculant sludges found at low and intermediate organic loadings. The linear removal rate for each compound increased linearly with increasing biological solids concentration. Overall organic removal, as measured by COD or TOC from a mixture of three or five linearly-removed simple compounds by an activated sludge acclimated to these compounds is actually a summation of the removals of each of the simple compounds. The removal of these mixtures can approximate first order kinetics.

Keywords: activated sludge, kinetics, biological treatment, chemical oxygen demand, cultures, organic matter, rates, sewage treatment, waste water treatment, linear substrate removal and soluable substrate.

EFFECT OF OXYGEN TENSION ON O2 UPTAKE AND SLUDGE YIELD IN COMPLETELY MIXED HETEROGENEOUS POPULATIONS

Merck Sharp and Dohme Research Labs., Rahway, N.J.; and Oklahoma State Univ., Stillwater
M.D. Rickard and A.F. Gaudy
Proceedings, Industrial Wastes Conference, 23rd, pages 883–893 (May 1968)

Operation of a completely mixed steady-state reactor at constant agitation (velocity gradient) but varying oxygen tension has shown that oxygen uptake rate and biological solids yield remained relatively constant for the range of DO concentrations between 1.4 and 7.1 mg/l. In addition, no effect was noted on the amount of RNA or protein contained in the cells. Also, as oxygen concentration was increased, there was a slight increase in DNA content of the cells, and a small improvement in both COD and glucose removal efficiency. There was a significant decrease in carbohydrate content of the cells. Concerning oxygen uptake rate, it may be concluded, based upon the present results and the work previously reported, that agitation of the system exerts an effect independent of oxygen tension at values above those accepted for critical DO concentration.

Keywords: mixing, oxygen requirements, activated sludge, biological treatment, waste water treatment, completely mixed system, oxygen tension, oxygen uptake and sludge yield.

THE RELATION BETWEEN SLUDGE VOLUME INDEX AND SLUDGE CONTENT IN THE ACTIVATED SLUDGE PROCESS

Instituut voor Gezondheidstechniek TNO, Delft (Netherlands)
J.A. Somers
Water Research, Vol. 2, No. 5, pages 563—573 (May 1968)

To characterize the sedimentation properties of activated sludge in the activated sludge treatment process, the determination of the sludge volume index (SVI) is important. Experiments were conducted in the oxidation ditch at Oudewater. A slow rise of SVI 45-55 to 70-90 was noted during the years 1962—1964. It is felt that the wide divergence may be due to inhomogeneities in the settling sludge mass and varying sludge qualities in the period of two years. Experimental methods were adopted to determine the SVI by artificially varying sludge contents. The results from Oudewater showed that SVI increases as the sludge content increases. However, for the highest sludge content, a lower SVI was noted. Sludge from Sancta Marcus (plant with bulking sludge) shows a different result. In this case SVI was lower when the sludge content was higher. Interpretation of the results from different sludges pointed that the diameter of the settling glass might influence SVI.

Keywords: sludge, activated sludge, sedimentation, sludge treatment, sewage treatment, waste water treatment, sludge volume index, sludge content, variation, bulking sludge, vessel diameter, grain diameter, flow velocity and pore volume.

DYNAMICS OF MICROBIAL PROCESS

Clemson Univ., S.C. Dept. of Environmental Systems Engineering
H.R. Bungay and J.F. Andrews
Water and Sewage Works, Vol. 117, No. 3, pages 77—80 (March 1970)

Although many processes are available for the improvement of effluent quality, the operation of biological waste treatment process at or near peak efficiencies provides considerable economic promise. Process control for biological treatment plants has many possibilities as well as several pitfalls due to the dynamics involved. Currently, some of the indices which can be monitored rapidly (e.g., flow rate, pH, temperature and DO) do not permit complete process control. Others such as BOD take considerable time for assay and its value as a short-term process control is limited. This problem is further complicated by sampling techniques commonly employed. Examples of control processes now in use are discussed. However, most control systems are of the feed-back type from the final effluent stream. In these cases it is often too late to correct a mistake in a biological system. Feed forward control is necessarily applied to systems with either very short or very long response times. Feed-forward control presupposes sufficient understanding of the system to predict

the effects of the input notables. When applied to a biological treatment system this means a model of reasonable accuracy must be available. The Monod equation could be helpful in a control system based on population dynamics and nutrient concentration. Long-term projects to provide adequate workable process controls for anaerobic digestors and a forward-feed control system for a conventional waste treatment plant are discussed. Parameters for the digestor include methane production, temperature, pressure and flow rate.

Keywords: biological treatment, efficiencies, waste treatment, effluents, analog computers, digital computers, methane, biological communities, aerobic treatment, anaerobic treatment, anaerobic digestion, waste water treatment, effluent quality and methane production.

EVALUATION OF THE KRAUS MODEL OF ACTIVATED SLUDGE BULKING

Northwestern Univ., Evanston, Ill.
W.O. Pipes and F.S. Meade
Proceedings Industrial Waste Conference, 23rd, pages 111—125 (May 1968)

Most of the proposed kinetic models of the activated sludge process interpret effluent BOD as being caused by organic matter which was originally present in the influent waste, but not removed in the aeration tank. Sludge solids lost in the effluent from the secondary settling tank will cause a high effluent BOD which is not due to unchanged organic matter from the influent. Bulking sludge can lead to the loss of sludge solids in the effluent, the amount of which could be predicted from the sludge volume index in a formulation developed by Kraus. An evaluation of the Kraus model was made based on two hypotheses: (1) the sludge volume index of a sludge sample remains constant with respect to time if no new sludge particles are formed, and (2) the sludge volume index of a mixture of two different sludge samples is the weight fraction sum of the SVI of each sample. The SVI of most samples of normal sludge (SVI 100 ml/gm) will remain constant during aeration for a few days. The mixture of two different sludge samples is not necessarily the weight fraction sum of the SVI of each sample.

Keywords: activated sludge, evaluation, kinetics, mathematical models, sludge, biochemical oxygen demand, organic matter, sludge treatment, bulking, Kraus model, sludge volume index and solids.

TRANSIENTS IN THE ACTIVATED SLUDGE PROCESS

Sterling Drug, Inc., Rothschild, Wis. Zimpro Div.
P.V. Knopp, D.G. Watts and G.A. Rohlich
Proceedings Industrial Waste Conference, 23rd, pages 894—913 (May 1968)

Aspects of modeling the dynamics of the completely mixed activated sludge process are discussed and estimates of the effects of variation in the concentration of organic material in the treatment plant effluent are presented. The usefulness of frequency response analysis of input-output records from the activated sludge process was demonstrated. COD was shown to be a poor indicator of system performance.

Keywords: activated sludge, dynamics, effects, frequency analysis, organic loads, model studies, mathematical models, organic matter, variable, waste water treatment, shock loads, transients and concentration.

TYPES OF ACTIVATED SLUDGE WHICH SEPARATE POORLY

Northwestern Univ., Evanston, Ill.
W. O. Pipes
Journal of the Water Pollution Control Federation, Vol. 41, No. 5, pages 714—724 (May 1969)

Practically all problems of the activated sludge process are manifest by poor separation of sludge in the secondary sedimentation tank and an increase in effluent BOD because of respiratory oxygen consumption by sludge or organisms in the effluent. Loss of sludge organisms in the effluent may be caused by any or all of three things: (1) Poor design of the secondary sedimentation tank which results in the loss of septic sludge or billowing sludge in the effluent. (2) Rising sludges produced by biological phenomenon when overaerated sludge is produced by mechanical phenomenon. Both of these phenomenon are understood well and can be eliminated by corrections in the operation of the aeration tank. (3) The formation of a type of sludge which settles poorly. Dispersed growth, while not actually a form of activated sludge may form in an activated sludge process. Continuous formation of the dispersed growth indicates the entire waste treatment system was conceived poorly and should be redesigned completely. Bulking sludge, floating sludge, pinpoint floc, and deflocculated sludge are each complexes of several different types of sludge. Each needs further study before separation into component types and solution to specific problems is possible. Given adequate capacity in secondary sedimentation tank and return sludge pumps, an activated sludge process can be operated successfully with a bulking sludge to produce an excellent quality effluent. There is no known way to get a good quality effluent from an activated sludge process which is producing large quantities of floating sludge, pinpoint floc or deflocculated sludge.

Keywords: activated sludge, settling basin, sludge, settling velocity, aeration, biochemical oxygen demand, microorganisms, growth stages, performance, sewage treatment, waste water treatment, bulking, characteristics and sludge volume index.

INFLUENCE OF TURBULENCE ON THE ACTIVITY OF ACTIVATED SLUDGE FLOCS

Technische Hochscule, Karisruhe (West Germany)
L. Hartmann and G. Laubenberger
Journal of the Water Pollution Control Federation, Vol. 40, No. 4, pages 670—676 (April 1968)

Experiments related to the influence of turbulence on the activity of activated sludge flocs reveal the following results: (1) At high concentrations of organic material in the mixed liquor the transport of oxygen from the environment to the cell surface is the rate limiting link in the chain of biodegradation reactions. An increase in the oxygen pressure in the environment also results in an increase in the oxygen consumption by the floc. (2) Turbulence has a double influence: (a) the breaking apart of the agglomerated flocs into the bacterial colonies which are the smallest units of the floc, and (b) the exchange of contact area between bacteria and environment. Both phenomenon result in an increase of oxygen uptake.
(3) Deflocculation starts while the fluid is still in laminar movement and extends to some degree into turbulent conditions. At Reynolds Number of around 5000 no further influence of

water movement on the physical properties of the floc seem to occur. The influence of turbulence on the exchange of the contact layer between bacteria and water occurs mainly between Reynolds Numbers 5000 and 9000.

Keywords: turbulence, oxygenation, Reynolds Number, activated sludge, dissolved oxygen, microorganisms, temperature, flocculation, uptake rates and oxygen tension.

SUBSTRATE UTILIZATION AND HIGH BIOLOGICAL SOLIDS CONCENTRATION

Oklahoma State Univ., Stillwater
P. Krishnan and A. F. Gaudy, Jr.
Journal of the Water Pollution Control Federation, Vol. 40, No. 2, Part 2, pages R54—R66 (Feb. 1968)

Laboratory-scale studies of batch activated sludge units with glucose and sorbitol as carbon sources showed that no relation existed between immediate uptake and initial solids concentration, for concentrations of 1,500 to 4,700 mg/l. It was observed in making studies with sorbitol and glucose and other studies in the laboratory, that during substrate removal using relatively high initial biological solids, most of the substrate is channeled into carbohydrate synthesis and that after this, protein is synthesized from the carbohydrate store, i.e., the two syntheses are observed to occur in essentially a sequential manner. The ability of high solids systems to remove substrate in the complete absence of protein synthesis is rigorously demonstrated by the experiement using chloramaphenicol. The results of the sorbitol experiments throw a particular light on the question of adsorption as a primary mechanism of substrate removal. No evidence for adsorption could be found, but additional evidence for the purely biochemical mechanism is put forth.

Keywords: activated sludge, concentration (composition), kinetics, degradation (decomposition), sewage treatment, waste water treatment, chemical oxygen demand, adsorption, carbohydrates, sludge, protein, microorganisms, metabolism, biological solids and Warburg.

FLOCCULATION OF BULKED ACTIVATED SLUDGE WITH POLYELECTROLYTES

Northwestern Univ., Evanston, Ill.
P.C. Singer, W.O. Pipes and E.R. Hermann
Journal of the Water Pollution Control Federation, Vol. 40, No. 2, Part 2, pages R1—R9 (Feb. 1968)

Bulk sludge can be flocculated and certain cationic polyelectrolytes are flocculants of bulk activated sludge. The optimum concentration for the two cationic polymers studied were found to depend on the initial sludge volume index and on the suspended solids content. The greater the suspended solids concentration, the greater was the polymer requirement, and the greater the final settled volume. As more polymer is added beyond the point of maximum flocculation, the flocculation, the floc becomes larger resulting in greater settled volume due to trapped water. The use of cationic polymers in flocculated bulk sludge resulted in the discharge of a clear stable effluent at dosages of between 2 and 3 mg/l. However, it was also found to be successful at a dosage of 50 mg/l. The treatment costs were: alum, $9.40/ million gallons; cationic polymer A, $6.50/million gallons; cationic polymer B, $20.00/

million gallons. Sludge once coagulated by a polymer seemed resistant to subsequent polymer coagulation during experiments of recycling of sludge.

Keywords: activated sludge, flocculation, sphaerotilus, sludge, coagulation, costs, sewage treatment, electrolytes, bulking, polymer and settling.

MODEL STUDY OF COLLOID REMOVAL

Minnesota Univ., Minneapolis
W.J. Maier
Journal of the Water Pollution Control Federation, Vol. 40, No. 3, Part 1, pages 478—491 (March 1968)

Biological treatment of colloidal starch solutions is described in terms of a sequence of steps, any one of which may be rate controlling: (1) mass transfer of substrate from bulk liquid phase to cell or active enzyme site, (2) degradation of colloidal particles into smaller fragments to facilitate passage through the semi-permeable membrane of metabolising bacteria cells, (3) metabolism of the substrate particles within the cells to provide energy and building blocks for growth. Experimental results of two types of reactors are described using starch as a representative colloid. Results from process variable studies show that mass transfer is the rate controlling factor in a laminar film flow reactor which simulates trickling filter conditions. On the other hand, high rates of mass transfer are obtained in a well mixed reaction vessel simulating activated sludge conditions due to eddy current transport. Hydrolytic degradation of colloid starch into small soluble carbohydrates proceeds rapidly and does not appear to be rate limiting in either type of reaction. Hydrolysis is mediated by enzymes which are available outside the confines of the semi-permeable cell membranes. Enzyme activity was observed in cell-free filtrates, thus indicating some presence of free enzymes in solution. It is theorized that it should be possible to improve the efficiency of trickling filters by increasing the mass transfer. This could be accomplished by improved packing design and/or agitation.

Keywords: biological treatment, colloids, thin films, waste water treatment, efficiencies, slime, activated sludge, concentration (composition), costs, enzymes, trickling filter and starch.

EFFECTIVE MIXING ENERGY ON SLUDGE YIELD AND CELL COMPOSITION

Oklahoma State Univ., Stillwater
M.D. Rickard and A.F. Guady, Jr.
Journal of the Water Pollution Control Federation, Vol. 40, No. 5, Part 2, pages R121—R144 (May 1968)

Operation of a steady-state bacterial system at a constant dilution rate with varying agitation rates has shown that solids yield and oxygen uptake both vary with the amount of agitation provided. As a measure of agitation, the average velocity gradient G was measured. The decrease in solid yield with increasing turbulence appears to occur primarily at the expense of cellular carbohydrate. This results in the production of a sludge having a higher protein content at a higher agitation rate. On the basis of literature cited and work presented, five mechanisms are advanced to explain the increased oxygen uptake and decrease in solids yield.

These are: (1) change in predominance, (2) increased frequency of contact between cells and substrate, (3) production of smaller floc particles with resultant improved penetration of substrate and oxygen, (4) increase in the rate of oxygen transfer across cell liquid interfaces, (5) maintenance of a higher DO concentration with increasing turbulance. Although none of these mechanisms can be eliminated, the increased oxygen uptake probably results from the reduction in the cell liquid interfacial resistance to oxygen transfer with increase of mixing energy and decrease in the biological solids yield probably results from an increased ratio of respiration to synthesis.

Keywords: mixing, activated sludge, microorganism, dissolved oxygen, sewage treatment, biological treatment, sludge, laboratory scale, waste water treatment, chemical oxygen demand, biological oxygen demand, turbulance, bacteria, agitation, compositions, RNA and DNA.

KINETICS OF SUBSTRATE UPTAKE IN PURE AND MIXED CULTURE

Massachusetts Inst. of Tech., Cambridge Dept. of Nutrition and Food Science
R.I. Mateles and S.K. Chian
Environ Sci Technol, Vol. 3, No. 6, pages 569—574 (June 1969)

Laboratory models were used to study the rates of substrate uptake by various microorganism cultures obtained from a local polluted stream. Acetate production amounted to 15 percent of the carbon source used in a glucose-butyrate feed of a culture that was carbon-limited. The growth rate was 1 hr-sups-1 and the dissolved oxygen pressure was 0.1 atm. There have been no previous reports of acetate production by a carbon-limited continuous culture and current theory says there should be none. The experiments indicated that complete analysis of media leaving a continuous culture or activated sludge process is necessary because of the appearance of catabolities in the effluent. Acclimatization should be carried out under flow conditions identical to those for the test. The steady state condition was reached after 10 to 25 residence times rather than the 5 or 6 usually reported.

Keywords: kinetics, activated sludge, cultures, mathematical models, model studies, carbon, biokinetics, Monod equation, zero order, pure culture, mixed culture, continuous culture, glucose, lactose, butyrate, acetate, steady-state, residence time and batch culture.

TEMPERATURE AND RETENTION TIME RELATIONSHIPS IN THE ACTIVATED SLUDGE PROCESS

Rutgers—The State Univ., New Brunswick, N.J.
J.V. Hunter, E.J. Genetelli and M.E. Gilwood
Proceedings, Industrial Waste Conference, 21st, (May 3, 4, 5, 1966), Purdue University, Vol. L, No. 2, pages 953—963 (March 1966)

As effluent standards become more strict, treatment methods previously rejected for economic reasons become more attractive. Temperature and retention time have been, investigated as possibly coming within the economical range in the near future. Increasing temperatures between 4° C and 45° C effected little change in BOD or SS removal efficiencies, but did result in decreased sludge carbohydrate and volatile matter contents, and increased sludge nitrogen content. Increased temperature also caused increased rotifer and protozoan population, while decreasing filamentous organisms and resulting in less MLSS accumulation. There was no uniform trend either for DNA content or SVI with temperature. Increased retention time caused decreased MLSS accumulation and higher BOD and SS removal efficiencies, while sludge volume index was not directly affected. From this study sludge, DNA content was shown to be a better indicator of sludge bulking than the general appearance of the sludge under microscopic examination.

Keywords: temperature, protozoa, rotifers, nitrogen, evaporation, biochemical oxygen, demand, activated sludge, waste water treatment, sludge treatment, retention time, synthetic wastes, SVI-sludge volume index, DNA-desoxy ribonucleic acid, filamentous microorganisms, bulking sludge and suspended solids.

PROCESS CONTROL FOR ACTIVATED SLUDGE

General American Transportation Corp., Niles, Ill.
C. Zaander and B. Johnson
Proceedings, 22nd Industrial Waste Conference (May 2, 3, 4, 1967), Purdue University, Vol. LII, No. 3, pages 403—413 (July 1968)

General American was asked to study the feasibility of automating an activated sludge plant. To do this parameters requiring measurement had to be identified and interrelationships between the various parameters had to be discovered in order to affect continuous control. Once mathematical models were set up it became apparent that sludge recycle had an important effect on the quantities which required measurement and control. Consequently, three types of recirculation schemes were considered: (1) constant BOD reduction ratio, (2) constant BOD in effluent, (3) and constant weight of returned sludge. These processes possess a certain measure of self regulation which allows them to cope with changes in the influent and the environment, but each process has one unique measurement requirement in the return flow.

Keywords: activated sludge, mathematical models, aeration, effluents, dissolved oxygen, biochemical oxygen demand, waste water treatment, water pollution control, return sludge flow, return sludge concentration and recirculation.

ACTIVATED SLUDGE ATP: EFFECTS OF ENVIRONMENTAL STRESS

Florida Univ., Gainesville Dept. of Environmental Engineering
P.L. Brezonik and J.W. Patterson
Journal of the Sanitary Engineering Division, American Society of Civil Engineers, Vol. 97, No. SA 6, pages 813—824 (Dec. 1971)

A study was undertaken to determine the response of sludge ATP to stresses imposed on the sludge environment and to demonstrate the utility of ATP measurements in determining changes in sludge activity. It was concluded from the experiments that ATP is a specific measure of sludge activity. Under constant environmental conditions, it can be used to estimate viable biomass in sludge. Measurements of ATP under varying environmental conditions indicate that activated sludge is relatively insensitive to abrupt temperature changes up to about 37 degrees C and that activated sludge organisms can withstand anoxic conditions without loss in viability for at least short (several hours) periods of time. The ATP content per cell is affected by substrate loading. ATP is also a sensitive and rapid indicator of toxic stress by heavy metals and industrial waste toxicants, such as mercury, nickel, copper, and cyanide, in activated sludge, and therefore may be useful as a means of monitoring biomass in waste treatment plants containing industrial effluents.

Keywords: waste water treatment, biochemical oxygen demand, biomass, indicators, activated sludge, sludge treatment, cultures, enzymes, respiration, chemical oxygen demand, bioluminescence, metabolism, temperature, heavy metals, water pollution effects, copper, industrial wastes, waste water treatment, E. coli, toxins, bioindicators, adenosine triphosphate, luciferase, dehydrogenase, cyanides, nickel, mercury, phosphorylation, aerobacter aerogenes, streptococcus faecalis, bacillus subtilis, pseudomonas fluorescence and survival.

EFFECT OF TEMPERATURE ON SUBSTRATE REMOVAL IN ACTIVATED SLUDGE

Kansas Univ., Lawrence
C. Palmerlee
Master's Thesis, University of Kansas (1970)

Both batch-fed and continuous feed activated sludge units were operated both at room temperature (22 deg C) and at 1-5 deg C. All other operational variables were held as nearly constant as possible. The substrates fed to the reactors were glucose and acetic acid-sodium acetate solutions. The operational cycle of the batch units consisted of 23 hours aeration, wasting of one liter of mixed liquor, one hour of sedimentation, wasting of one liter of supernatant, addition of feed and nutrients, adjustment of level with tap water, and then aeration again. The continuous fed unit was seeded with primary domestic sewage and substrate was added continually. Parameters monitored included mixed liquor volatile suspended solids, mixed liquor suspended solids, mixed liquor COD, effluent suspended solids, effluent and soluble COD and effluent and soluble BOD5. The data obtained demonstrated that conventional activiated sludge systems operating under sustained low temperatures would require a longer aeration time to achieve removals comparable to those obtained at higher temperatures. In addition, low temperature operation also experienced difficulty in solids removals. Continuous-fed systems experienced less temperature 'shock' than batch fed systems, but solids removal difficulties were present for all low temperature operations.

Keywords: activated sludge, temperature, waste water treatment, metabolism, bacteria, protozoa, growth rates, sludge, acclimatization, adsorption, aeration, chemical oxygen demand, biochemical oxygen demand, suspended solids and BOD5.

THE INFLUENCE OF TOXIC SUBSTANCES ON THE FUNCTIONING OF BIOLOGICAL PURIFICATION PLANTS

Service pour le Controle du Pollution de l'Aire (Switzerland)
L. Thelin
Z Praventivemed. 15 (3): pages 203—205 (1970)

Procedures of biological purification-bacterial filters or activated sludge-make use of the action of a population of microorganisms to destroy foreign matters in used water. In order to maintain this population in an active condition and to obtain sufficient purification, rapid variations in the charge or discharge of used water should be avoided. The influx of toxic residual products should also be avoided. Examples of agricultural water: arrival of liquid manure, and industrial water: discharge of acid, cyanide or heavy metal are discussed.

Keywords: activated, agricultural, bacterial, biological, filter, functioning, industrial, maintenance, plants, population, purification, sludge, substances, toxic, and waste water.

POPULATION DYNAMICS IN BIOLOGICAL TREATMENT PLANTS

Water Pollution Research Lab., Stevenage (England)
A. L. Downing and G. Knowles
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 117—136 (1966)

Very little basic information is presently known about the relative numbers, activities, and nutritional requirements of the various types of microorganisms that can gain access to activated sludge plants. Predictions of removal of anionic detergents and degree of nitrification based upon population dynamics correspond very well with actual observed values. Mathematical models based on growth and decay rates are formulated to explain the rate of removal of certain substrates. Removal of a particular substrate from a waste water depends upon whether or not conditions existing in the treatment system are favorable for the growth of organisms capable of degrading the substance in question. The critical variables are temperature, pH, detention time, and whether or not any substances specifically toxic to the organism in question are present. Also, a certain acclimatization period may be required to establish the growth of a new organism. Hopefully, a more thorough knowledge of the growth patterns of the mixed microbial populations present in biological reactors will provide more insight into design conditions and procedures in the future.

Keywords: kinetics, bacteria, protozoa, mathematical model, biodegradation, metabolism, acclimatization, nitrification, detergents, aeration, hydrogen ion concentration, activated sludge, water purification, biological treatment, microorganisms, waste water treatment, treatment facilities, population dynamics, nitrosomonas and anionic detergents.

DISCUSSION OF 'POPULATION DYNAMICS IN BIOLOGICAL TREATMENT PLANTS'

Water Pollution Research Lab., Stevenage (England)
R. E. McKinney
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 137—140 (1966)

The parameters which are controlled by an engineer in an activated sludge plant are, waste retention time, pH, nutrient elements, mixing, oxygen, microbial mass, and temperature. All other elements are fixed by the nature of the waste and the metabolic rates of the microorganisms. Population dynamics should be approached from the fundamentals, rather than from complex empirical mathematics. A very carefully designed and controlled study of the combined bacterial and protozoan system is needed to provide engineers with a better fundamental understanding of population dynamics.

Keywords: bacteria, protozoa, metabolism, microorganisms, activated sludge, detergents, oxygen demand, hydrogen ion concentration, nutrients, mixing, oxygen, temperature, nitrification, waste water treatment, mixed microbial populations, pure culture, population dynamics, waste retention time, empirical and microbial mass.

DISCUSSION OF 'POPULATION DYNAMICS IN BIOLOGICAL TREATMENT PLANTS'

Water Economics Research Inst., Warsaw (Poland)
J. Ganczarcyk
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 136—173 (1966)

The work done by Downing and Knowles is supported, to a large extent, by work done in Poland by Ganczaryck, although several differences were noted. First of all, the sorption of certain substances on activated sludge flocs was selective and did not resemble closely the phenomenon of the Freundlich Isotherm. Also, the substances were often oxidized partially to form equally complicated intermediates, making determination of the biodegradable portion quite difficult. Secondly, the formulations could not explain fully the influence of physical factors on population dynamics, the interaction of activated sludge population in the degradation of some organics, or the limitation of one stage activated sludge processes in the elimination of some difficult organics.

Keywords: mathematical models, biodegradation, activated sludge, detergents, organic compounds, nitrification, biological treatment, waste water treatment, population dynamics, intermediates, enrichment and over-aeration.

DISCUSSION OF 'DETERMINATION OF ACTIVATED SLUDGE ACTIVITY—A POSSIBILITY OF CONTROLLING ACTIVATED SLUDGE PLANTS'

Hydraulic Research Inst., Prague (Czechoslovakia)
M. Effenberger
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 94—97 (1966)

A difference in the level of turbulence will cause a difference in the level of biological activity in an activated sludge tank. However, measurements must be taken at the temperature at which the aeration tank is operating. If a different temperature is used to incubate the samples then results cannot be considered accurate. Lenhard, Nourse, and Schwartz recommend adjusting the pH of the solution during the standard test but this would cause the conditions to deviate from actual aeration tank conditions. Enzymic activity depends on the fact that the enzyme proteins are polyvalent dipolar ions which can exist in a number of forms depending upon the pH value of the substrate. Some of these forms are more active than others, resulting in considerable experimental error. Biological population changes in response to changes in the organic loading. Generally lower loads were characterized by protozoal sludge, while higher levels of loading resulted in bulking or filamentous sludge. A pilot plant activated sludge unit was operated in order to establish the relationship between total dehydrogenase activity and oxidation-reduction potential. The samples were kept at the temperature of the mixed liquor in the aeration tank. Dissolved oxygen content varied between 1 and 2 mg/l. Increasing dehydrogenase activity resulted in decreased oxidation reduction potential in the mixed liquor. However, the gradient of the line expressing the relationship of the two values was given by the technical and technological conditions of the activated sludge process.

Keywords: pilot plant, incubation, activated sludge, dissolved oxygen, biochemical oxygen demand, sludge treatment, waste water treatment, TTC, dehydrogenase, total activity, specific activity, HURD, INKA, triphenyl formazone, aeration tank and mixed liquor.

EFFECT OF CENTRATE FROM SOLID BOWL CENTRIFUGE ON ACTIVATED SLUDGE PROCESS

Metropolitan Sanitary District of Greater Chicago, Ill.
T.J. Kennedy and A.J. Kaplovsky
Proceedings, Industrial Waste Conference, 22nd (May 2, 3, 4, 1967), Purdue University, Vol. LII, No. 3, pages 145—164 (July 1968)

Two identical activated sludge pilot plants were constructed to study the effects of the recirculation of centrate from a sludge solids bowl-type centrifuge. One of the reactors received centrate, and the other was used as a control. Laboratory analysis determined that the centrate contained mainly generated fines consisting of dissolved zoogloeal masses and fragments of filamentous forms. It was also determined that primary treatment could remove the bulk of centrate solids from centrifugation installations operating at solids recoveries of at least 70%. Centrate solids, obtained from centrifugation of total waste solids output with 80% solids recovery, continuously returned to a conventional activated sludge plant produced no detrimental effects upon effluent quality or the activated sludge process itself. Consistently higher sludge volume indices were noted in the re-cycled reactor, however, but a certain limit was reached beyond which the SVI deteriorated no further. One possible explanation of this phenomena is the breakup of filamentous organisms in the centrifugation process, and their subsequent accelerated cell division and growth when placed in a biologically active reactor.

Keywords: centrifugation, metabolism, phosphate, nitrogen, microorganisms, coliforms, activated sludge, chemical oxygen demand, biochemical oxygen demand, waste water treatment, sludge volume index, centrate, volatile suspended solids and filamentous organisms.

EFFECTS OF AERATION TIME ON SOLUBLE ORGANICS DURING ACTIVATED SLUDGE TREATMENT

Geological Survey, Washington, D.C., Water Resources Div.
D.A. Rickert and J.V. Hunter
J Water Pollu Contr Fed. 43 (1): pages 134–138 (1971)

The effects of aeration time on soluble organic strength parameters were studied during the conventional activated sludge treatment of domestic sewage. Plug flows of primary effluent were sampled over 6-hr aeration periods, and the soluble fraction of each sample was analyzed for TOC (total organic carbon) and COD (chemical oxygen demand). Soluble TOC was reduced to a relatively stable level after 30 min of aeration, with a 70% average reduction in initial concentration. Soluble COD was reduced to a relatively stable level after 1 hr of aeration, with average reduction of 77%. COD:TOC ratios decreased steadily over the 1st hr of aeration and fluctuated irregularly thereafter. Comparison of COD:TOC ratios to TOC data suggested that a transfer of soluble organics occurred between the aqueous phase and bacteria over the aeration interval from 30 min to 1 hr. The average oxidation state was estimated for the organic carbon in each sample.

Keywords: activated, aeration, bacteria, carbon, chemical, organic, organics, oxygen, sludge, soluble and time.

THE MATHEMATICS OF ACTIVATED SLUDGE CONTROL

Brown and Caldwell, San Francisco, Calif.
W.R. Uhte
Journal of the Water Pollution Control Federation, Vol. 42, No. 7, pages 1292–1304 (July 1970)

For the use of the mean cell residence or the solids retention time in the control of an activated sludge system, one must select the desired time, compute the total solids present in the system and determine the total volatile solids to be wasted per day. The solids in the system may be expressed as the sum of those in the aeration facilities secondary sedimentation units and the sludge return system. Solids are wasted both over the effluent weir and through the solids disposal system. Numerical examples show these computations for conventional, step feed, high rate and multiple step operations of an hypothetical plant. Assumed plant design is for a 18 mgd flow. The plant layout includes four aeration tanks, mixed liquor channel and return activated sludge channel, and four secondary sedimentation basins.

Keynotes: mathematical model, activated sludge, control, sludge, kinetics, design, suspended solids, wasting, computations and process control.

COMMON USE OF CONVENTIONAL ACTIVATED SLUDGE

THERMOPHILIC ACTIVATED SLUDGE PROCESS

Mississippi State Univ., State College
A. Shindala and J. E. Parker
Water and Wastes Engineering, Vol. 7, No. 3, pages 47–49 (March 1970)

The ability of thermophilic aerobic microorganisms to provide adequate treatment of a waste by activated sludge process under varying organic loading conditions is discussed. Laboratory data show that at 55 degrees C, with no solids return, the overall BOD reduction was 94% under varying organic loading conditions. Decreasing the detention time has no apparent effect on the BOD reduction efficiency. With a return solids ratio of 1:1, the average BOD reduction efficiency was 85%. A variation of mixed liquor suspended solids concentration from 200 to 650 mg/l had no apparent effect on the removal efficiency.

Keywords: activated sludge, thermophilic bacteria, biochemical oxygen demand, organic loading, waste water treatment, sewage treatment, raw sewage and solids return.

ANALOG SIMULATION OF ACTIVATED SLUDGE SYSTEMS

Kentucky Univ., Lexington
C. E. Burkhead and D. J. Wood
J of Sanit Eng Div, Proc Amer Soc Civil Eng, Vol. 95, No. SA3, Proc Paper 6631, pages 593–606 (June 1969)

Analog computer solutions of activated sludge design equations are presented for constant, shock, and periodic feed input conditions. From system responses of the aerated lagoon, extended aeration, and separate sludge wasting activated sludge systems to these different inputs, the authors draw the following conclusions: (1) the analog computer can be used to solve nonlinear differential equations for both steady-state and trainsient solutions; (2) operational changes caused by different plant influents; e.g., shock and periodic loads, and response comparisons of different activated sludge systems to such inputs can be determined using the analog computer; and (3) research is necessary to confirm the ability of present design expressions to describe transient changes in actual plants.

Keywords: computer design and analog simulation.

EFFECT OF DISSOLVED OXYGEN CONCENTRATION OF THE METABOLIC RESPONSE OF COMPLETELY MIXED ACTIVATED SLUDGE

Oklahoma State Univ., Stillwater. Dept. of Civil Engineer
G.J. Tharbaraj and A. F. Gaudy, Jr.
Journal of the Water Pollution Control Federation, Vol. 41, No. 8, Part II, pages R322–R335 (Aug. 1969)

Steady state conditions were established in laboratory activated sludge units at specific levels of dissolved oxygen (7.2, 7.4, 3.2, and 1.3 mg/l), the concentration of substrate in the feed was increased, observation was made of the transient and new steady state behavior, and in some cases substrate concentration was reduced to the original level and observation made of the transient and new steady state. Steady state valves of respiration rate, substrate channelled into respiration, solids yield, COD removed per weight of ammonia consumed, and protein and carbon-hydrate concentration of cells were found to be independent of dissolved oxygen concentration in the range studied (0.4 to 7.4 mg/l). The transient response consisted of two distinct sequential responses. The first was a metabolic or physiological reaction carried out by the population present prior to the shock. During this initial response lower dissolved oxygen levels gave rise to higher COD in the effluent. The second transient response involved a change in the predominate population; gave rise to increased COD, solids and intermediates in the effluent; and was independent of dissolved oxygen concentration.

Keywords: activated sludge, dissolved oxygen, chemical oxygen demand, sewage treatment, metabolism, waste water treatment, shock load, transient behavior and steady state.

ROLE OF ACTIVATED SLUDGE FINAL SETTLING TANKS

Illinois Univ., Urbana. Dept. of Civil Engineering
R.I. Dick
Journal of the Sanitary Engineering Division, ASCE, Vol. 96, No. SA2, pages 423–436
(April 1970)

The final settling tank in the activated sludge process has two functions: clarification and thickening. Conventional design procedures have considered only the clarification function. However, inadequate performance of thickening functions produces adverse effects, including: loss of suspended solids to the effluent and insufficient suspended solids concentration in the sludge recycle which leads to lower mixed liquor suspended solids concentrations in the aeration tank. To assure proper performance of the final settling tank the tank should be sized for each function and the larger size should govern the design. The area required for thickening must be sufficient so that solids are applied to the tank at a rate less than the rate at which solids are able to reach the bottom of the tank. The rate at which biological solids reach the bottom of the tank is termed the flux rate. Characteristically, this flux rate passes through a minimum for some concentration of activated sludge present in the settling tank. This minimum flux rate acts as a bottleneck and governs the area required for thickening. Several methods for determining the limiting capacity are given in an illustrative example.

Keywords: activated sludge, sewage treatment, sedimentation, waste water treatment, thickening, final settling tank, flux rate, clarification and suspended solids.

CONTROL OF ACTIVATED SLUDGE BY MEAN CELL RESIDENCE TIME

California Univ., Berkeley, Sanitation Engineering Research Lab
D. Jenkins and W. E. Garrison
Journal Water Pollution Control Federation, Vol. 40, No. 11, Part I, pages 1905–1919
(Nov. 1968)

A rational description of activated sludge process is presented, with demonstration of the way in which the effect of process variables can be predicted and design and control principles improved. Using a modified Monod equation, substrate removal rate and mean cell residence time based on chemical oxygen demand removed per pound of volatile suspended solids are calculated. Basing activated sludge design parameters on mean cell residence time the authors show that the data from the Pomona Water Renovation Plant in California compare favorably with other studies. Results show that substrate removal rate and mean cell residence time are kinetically rational design, control, and operating parameters.

A standard rate of 0.2 0.5 lbs BOD/day/lb VSS compared to a mean cell residence time of between 5–15 days. A sample calculation is included.

Keywords: kinetics, activated sludge, chemical oxygen demand, waste water treatment, design, operation, microorganisms, nitrification, Monod equation and volatile suspended solids (VSS).

HYDRAULICALLY CONTROLLING SOLIDS RETENTION TIME IN THE ACTIVATED SLUDGE PROCESS

Yoder-Trotter, Orlob and Associates, Walnut Creek, Calif.
L. F. Walker
J Water Pollu Contr Fed. 43 (1): pages 30–39 (1971)

Solids control in the operation of the activated sludge process is vital. The hydraulic method of solids control is effective, simple, and has particular application in smaller plants with limited personnel. It has advantages over the most commonly used method of maintaining a constant mixed liquor suspended solids level. The fixed solids method of control does require a minimum of laboratory control but ignores the factor of food-to-microorganism ratio. A 2nd control method involves this ratio or, in other terms, the biochemical oxygen demand: volatile suspended solids ratio. A 3rd control method involves maintaining a constant solids retention time in the system. The latter is generally preferred because it produces the best effluent with a minimum amount of laboratory control work required. The hydraulic control method involves controlling solids retention time, no laboratory work, and only knowledge of plant flow and the sludge return rate. The use of such a control system is explained by actual plant examples.

Keywords: activated, biochemical, controlling, hydraulically, methods, optimal, oxygen, process, retention, sludge, solids, time, waste and water.

LOW TEMPERATURE ACTIVATED SLUDGE SETTLING

Alaska Univ., College
S.C. Reed and R.S. Murphy
Journal of the Sanitary Engineering Division, American Society Civil Engineering, Vol. 95, No. SA4, Proc Paper 6747, pages 747–767 (Aug. 1969)

This investigation is concerned with the temperature influence upon activated sludge sedimentation theory. Particular attention is focused on temperature effects on 'zone' settling velocity. The study is generated by research results in Alaska on aerated lagoons and sludge processes which indicated apparent high efficiencies requiring minimal thermal protection. Thus, basically convention treatment plant designs might be economically adaptable to cold weather regions without costly systems thermal protection. This study presents results of a series of settling tests using temperature and concentration as controlled variables. An empirical equation was developed defining the variations of zone settling velocity of activated sludge in terms of concentration, fluid temperature, and organic loading. Temperature effects diminish with increasing concentration. Equation affords rational basis for analysis of design requirements for cold region treatment facilities. Study concludes tentatively that the compression, or thickening, of sludge is independent of fluid temperature.

COMMON USE OF CONVENTIONAL ACTIVATED SLUDGE

Keywords: activated sludge, settling velocity, temperature, design, sewage treatment, 'zone-settling', activated sludge particle, sludge-blanket clarifiers, thermal protection, sludge, concentration, particles, clarification, Fairbanks (Alas), Strokes' Law and BOD.

KINETICS OF BIOLOGICAL TREATMENT

California Univ., Berkeley
E.A. Pearson
Advances in Water Quality Improvement, (Editors: Gloyna, E. F., and Eckenfelder, W.W., Jr.), Austin, Texas, Univ. of Texas Press, pages 381—393 (1968)

A consistent and rational basis for a kinetic description of both aerobic and anaerobic waste treatment systems is presented. The kinetic model for growth and enzyme substrate removal is based upon that of Michaelis-Menten, and substrate and cell material balance equations including a decay term constitute the basic kinetic descriptions of the process. The need for further laboratory and field determinations of applicable kinetic constants is emphasized. A summary of currently known data on aerobic constants is furnished. The use of kinetic modeling in interpreting biological processes, such as extended aeration is demonstrated. An extended aeration plant is one where the net growth rate is made to approach zero; that is, growth is about equal to decay. An analytical approach to maximum growth processes for application in nutrient removal operations is presented.

Keywords: aeration, biological treatment, biological properties, kinetics, equations (kinetics), mathematical models, oxygen demand, effluents, growth rates, growth stages, nutrients, extended aeration, biological processes, Michaelis-Menten growth model, system kinetics, kinetic models, organic substrate removal, biological process constants and nutrient removal.

PROCESS MODELING OF BIOLOGICAL WASTE TREATMENT

Texas Univ., Austin
D.M. Himmelblau and E.F. Gloyna
Available from NTIS as AD-715 726, $3.00 in paper copy, $0.95 in microfiche. Annual Progress Report No. 2, 14 pages (Oct. 10, 1970)

Laboratory scale aeration units have been employed to obtain and identify mathematical models of biological waste treatment. Sodium-24 was used as a tracer material since it doesn't affect the physical parameters of the fluid, it doesn't undergo any chemical reactions, and it is easily detectable in small concentrations. Data obtained is highly reproducible if periods of at least 8—10 residence times are used. However, the assumption of complete mixing was found to be applicable only in certain cases. When there wasn't complete mixing, results were not reproducible.

Keywords: mathematical models, aerobic treatment, biomass, aeration, tracer, waste water treatment, population balance techniques, mean residence time, complete mixing, pulse injection, concentration, sodium-24, variance, agitation and laboratory scale.

PROCESS OPTIMA IN ACTIVATED SLUDGE

Illinois Inst. of Tech., Chicago
S. Polocsik, R.B. Grieves and W.O. Pipes, Jr.
Proceedings, Industrial Waste Conference, 20th, (May 4, 5, 6, 1965), Purdue University, Vol. XLIX, No. 4, pages 197—209 (July 1965)

An effort has been made to analyze the effects upon the activated sludge process of first, baffling the aeration tank to provide three completely-mixed compartments of varying fractional volumes; second, of varying the input distribution of the waste to the three compartments, and third, of varying the recycle flow to the three compartments. Two-phase and one-phase kinetics were employed, with the latter utilized for the case of no sludge recycle. Optimum operation is achieved by dividing the aeration tank volume by baffling into three equal-size compartments. It is best to distribute the feed toward the front of the system while the recycle should be inserted toward the back end of the system.

Keywords: activated sludge, baffles, aeration, kinetics, nutrients, optimization and waste water treatment.

A STUDY OF THE ACTIVATED SLUDGE PROCESS AS A BACTERIAL GROWTH PROCESS

N. Westberg
Water Research, Vol. 1, pages 795-804 (1967)

A model of a completely mixed activated sludge process operating under a steady-state condition is developed from material balances. The rate of substrate utilization was assumed to be zero order with respect to substrate concentration and first order with respect to bacteria concentration. Moreover, the rate of substrate release through lysis of the dead bacteria cells is proportional to the product of the concentration of both the living and dead bacteria. The net growth rate of new cells is directly proportional to the bacteria concentration minus a quantity that is inversely proportional to the F/M ratio. Results of the calculations as functions of the flow factor, retention time, and sludge age are tabulated one plotted graphically.

Keywords: mathematical model, cell lysis, and material balances.

FILAMENTOUS MICROORGANISMS AND THE BULKING OF ACTIVATED SLUDGE

Rutgers—the State Univ., New Brunswick, M.J. Dept. of Environmental Sciences
M.S. Finstein and H. Heukelekian
Proceedings, Industrial Waste Conference, 20th, (May 4, 5, 6, 1965), Purdue University, Vol. XLIX, No. 4, pages 175—181 (July 1965)

Quantitative data with which to assess the influence of filamentous microorganisms on the settleability of activated sludges is presented. Flocs from 4 activated sludge plants were characterized with respect to their diameters and total length of associated filamentous microorganisms per floc. Flocs ranged from 0.02—0.2 mm in diameter and 0.0—2.0 mm in length. No consistent relationship was found between floc diameter and SVI but the more filamentous samples invariably had a higher SVI.

Keywords: microorganisms, activated sludge, waste water treatment, microbiology, bulking and sludge volume index.

COMMON USE OF CONVENTIONAL ACTIVATED SLUDGE

STUDY OF AEROBIC THERMOPHILIC PROCESSES FOR WASTE TREATMENT

Clemson University, S.C., Environmental Systems Engineering Program
C.R. Nichols
Environmental Systems Engineering Report 66-1 (June 1966)

An investigation was conducted to determine the substrate utilization rate, organism growth rate and yield, organism decay rate, and kinetic constants for organisms grown in continuous-flow completely mixed reactors with turbine aerators. The constants were found for identical reactors under identical conditions except for the temperature in the mesophilic reactor being 26° C and 54° C in the thermophilic reactor. The reactors were closed systems with provisions for the monitoring of influent and effluent gas and liquid streams. The substrate consisted of 1800 mg/1 of glucose as the carbon and energy source and other elements necessary for growth. Evaluation of the data indicated that an oxygen limited situation existed at the lower residence times, causing a change in the original proposed mathematical model which placed limitations on the data. The thermophiles were especially limited by this situation due to their high metabolic rate and low solubility of oxygen in water at the thermophilic temperatures. Little difference was found in the continuous flow constants at the two temperatures. This was not expected and was probably due to oxygen limitations at the lower flow rates.

Keywords: aerobic conditions, aeration, oxygen, mathematical model, temperature, wastewater treatment, metabolism, thermophilic conditions, and mesophilic conditions.

SETTLING CHARACTERISTICS OF ACTIVATED SLUDGE AT LOW TEMPERATURE

Cold Regions Research and Engineering Lab., Hanover, N.H.
S. Reed
Available from NTIS as AD-717 239, $3.00 in paper copy, $0.95 in microfiche. CRREL Technical Report 203, 30 pages (Nov. 1970)

A series of activated sludge settling tests were observed with particle concentration and temperature as the controlled variables. Based on the experimental data, an equation defining settling velocity in terms of concentration, fluid temperature, and organic loading was developed. Although empirical in nature the equation provides a rational basis for the determination of temperature influence and should have special value for cold regions designs. It was possible to describe the results of other investigations with this equation.

Keywords: sewage, arctic regions, chemical precipitation, mathematical analysis, design, sewage treatment, activated sludge process, clarification and settling.

OPTIMAL CONTROL OF BIOLOGICAL REACTORS

A. E. Molvar
Ph. D. Dissertation, University of Connecticut
Unvir Microfilm Order No. 72-32-157 (1971)

Material balances in conjunction with the Monod kinetic model yield a set of difference-differential equations that govern the dynamic behavior of a continuous flow stirred tank activated sludge reactor. Since activated sludge reactors are subject to variations in the influent concentration and flow rate, compensating control is usually necessary to hold the effluent concentration within suitable levels. Optimal control theory was applied to the activated sludge reactor to minimize the transition time (time optimal) and the integral of the error squared (set point enforcement). The performance of several specific feedback controllers and combination feed-forward feedback controller were also simulated for a reactor perturbed by shock, step, and sinusoidal disturbances. In general, all the tested controllers performed adequately for step, low frequency (0.1 cycle/residence time), and high frequency (10 cycles/ residence time) inputs. The control action was poorest at the middle frequency range (around 1 cycle/ residence time). Relay control is the preferable mode since it is inexpensive, simple, rugged, and not prone to chatter for a majority of the reactors. Under certain operating conditions activated sludge reactors were shown to possess an inherent degree of self-control to compensate for changes in feed concentration. When delay in the settler was considered, only marginal differences were observed between the controller responses associated with the delay and nondelay models. The additional complexity and loss of generality produced by the delay model inhibit its usefulness; the nondelay model should suffice in most circumstances. Stability analyses performed on both the delayed and nondelayed models indicate that the constant flow stirred tank activated sludge reactor is stable over a wide range of operating conditions.

Keywords: activated sludge, Monod kinetics, difference-differential equations, optimal control, time optimal control, set point enforcement, load perturbations and stability analysis.

FEED FORWARD CONTROL OF AN ACTIVATED SLUDGE PROCESS

R. W. J. Brett, R. I. Kermode, and B. G. Burrus
Water Research, Vol. 7, pages 525—535 (1973)

The control of an activated sludge process is an inherently difficult problem. The nonlinearity of the process, the wide range of operating conditions, and the lack of a really suitable control variable all contribute to this difficulty. A computer simulation of a perfectly mixed aeration tank was used to show that feed-forward control is the most suitable control method for a wide range of operating conditions. In particular, proportional control with measurements of the substrate flow rate and manipulation of the rate of return sludge was as effective as much more complex combinations of feed-forward and feed-back controllers. There was some indication that on-off control would be highly effective.

Keywords: automatic control, bode plots, simulations, feed-forward and on-off control.

RESPONSE AND STABILITY OF COMPLETELY MIXED ACTIVATED SLUDGE REACTOR

H. E. Klei, Sundstrom, and A. E. Molvar
Chemical Engineering Progress Symposium Series, Vol. 65, No. 97 (1969)

A mathematical model of a completely mixed activated sludge reactor was developed by using Monod kinetics. The numerical solution of the resulting set of nonlinear differential equations was compared with the linearized analytical solution. The error between the nonlinear and linearized responses about an arbitrary steady state is shown for several step changes in inlet flow rate, carbon concentration, and sludge concentration. A stability analysis indicated that the reactor is stable over a wide range of operating conditions.

Keywords: activated sludge, math model, Monod kinetics, linearization, and stability analysis.

COMPUTER SIMULATION OF ACTIVATED SLUDGE PLANT OPERATION

P. G. Lacroix and D. E. Bloodgood
Journal Water Pollution Control Fed., 44, 1778 (1972)

The relationships of the important parameters describing the activated sludge process are not well defined, and the process has a reputation of being difficult to operate. A data analysis was conducted of available operation data of eight different conventional activated sludge plants in five Indiana cities. A unique activated sludge system analysis was performed. The activated sludge system was divided into two distinguishable subsystems, aeration and sedimentation tanks, and four mathematical models were developed to describe each of the eight activated sludge treatment plants. Extensive field data were used, and good multiple correlation coefficients were obtained. The sludge age parameter was found to be a better parameter to use than the sludge volume index in defining the properties of the activated sludge. Sensitivity analyses were conducted to determine the effect that changes in wastewater characteristics and operational parameters had on the system response.

Keywords: activated sludge process, biological waste treatment, computers, mathematical models, sensitivity analysis, simulation and sludge age.

A NEW APPROACH TO CONTROLLING BIOLOGICAL PROCESSES

Southwest Research Inst., San Antonio, Tex.
L. Hiser
Environmental Science and Technology, Vol. 4, No. 8, pages 648—651 (Aug. 1970)

Some criticism is given of the current use of the BOD test as a control parameter for waste water treatment systems. It is felt that separate parameters to describe 3 distinct variables—food, energy, and culture—would lead to a simpler and more widely understood concept of the biological system. Since carbon is a basic food supply of living matter, it is logical that it should be a primary parameter for describing both the food supply and the culture content from microbiological systems. A simplified carbon nomenclature is used to describe the many forms in which carbon can be present. In the liquid phase it includes dissolved organic carbon and dissolved inorganic carbon; the solid phase includes suspended organic carbon and suspended inorganic carbon; the gas phase includes gas organic carbon and gas inorganic carbon. It is suggested that the energy requirement can be determined as the total change in oxygen demand of the system coincident with the conversion of carbon. It is stated that this approach will assist in the breakdown of biological treatment process into a series of describable unit operations which are amenable to material balances and more precise descriptions of unit rate. Two advantages of this type of analysis are: (1) analytical time is reduced from days to minutes and (2) it is possible to make both materials and energy balances.

Keywords: biological treatment, control carbon, waste water treatment, sewage treatment, biochemical oxygen demand, energy, total oxygen demand and volatile solids.

TURBULENCE DIFFUSIVITY IN ACTIVATED SLUDGE AERATION BASINS

Utah Water Research Lab., Logan
A.A. Kalinske
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

In the study of complex turbulence fields in activated sludge aeration basins, one must consider the parameters which are pertinent to the particular process that is being considered. No overall general average characterization of the turbulence in such basins is of much value. The customary criteria of energy input (average velocity gradients) as calculated from the power input is not sufficient to characterize the turbulence involving air bubbles and floc matrices. Of greater importance are the turbulence intensities usually expressed as the mean square velocity function and the energy dissipating eddies, as shown by a turbulence spectrum. High intensity in small scale eddies of a size comparable to the floc will increase the various process transfer rates by increasing the applicable diffusivity and by floc disintegration to expose as much of the microbial surface as possible. Diffusers are reported to have inherent limits so far as controlling the intensity and scale of the turbulence is concerned, and mechanical means such as turbines are suggested to generate high localized fluid shear and large amounts of microturbulence. This is considered to be of particular importance where oxygen enriched air or pure oxygen may be used for treating strong wastes maintaining high values of DO or using high concentrations of suspensions.

Keywords: turbulence, diffusivity, activated sludge, aeration, waste water treatment, biological treatment, energy, mass transfer, mathematical model, kinetics, aeration basins, agitation, and gradients.

INVESTIGATION ON THE CONTROL OF FILAMENTOUS BULKING

Instituut voor Gezondheidstechniek TNO, Delft (Netherlands)
A. Pasveer
Advances in Water Pollution Research, Proceedings Fourth International Conference on Water Pollution Research, held in Prague, Czechoslovakia (April 21—25, 1969): London, Pergamon Press, Ltd, Sec II, Paper 14 (Sept. 1968)

An effort was made to gain further understanding of the phenomenon of bulking by isolating the causative organism and studying its properties. These properties will undoubtedly be influenced by the conditions in the activated sludge floc. Therefore, the conditions in the floc and at the floc boundary were also studied. Two years of investigation of an oxidation ditch with bulking sludge resulted in the conclusion that oxygen supply, growth of filamentous organisms, nitrification and denitrification were in some way connected. The causitive organism was found to be Escherichia coli, which shows filamentous growth at pH 5 to 6. Microscopically, the filamentous growth of E. coli is singularly like that of Sphaerotilus. High loads (of carbohydrates) together with a nitrifying flora prevailing in the activated sludge may lead to conditions in which E. coli can thrive in the floc in filamentous form. It is not claimed that every case of filamentous sludge must necessarily be a coli infected sludge. It is believed nevertheless that this type may be rather common, in light of the explanation given and the results of other investigators.

Keywords: activated sludge, control, bacteria, biological treatment, waste water treatment, bulking, filamentous and escherichia coli.

THE INFLUENCE OF WASTE WATER CONCENTRATION ON THE ACTIVATED SLUDGE PROCESS EFFICIENCY

Water Economics Research Inst. Warsaw (Poland)
J. Ganczarzyk and S. Bachanek
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

Waste water from the production of fiberboard contains a complicated mixture of dissolved and colloidal organic substances which has a range of concentration from 7,300 to 42,000 mg/l COD. These are primarily collodial carbohydrates and to a lesser extent furfurol, lower alphatic acids, alcolhols, aldehydes and ketones. Dissolved oxygen levels of 1 to 2 mg/l were maintained throughout the experiments as well as a constant ratio of mineral nutrients to the BOD load with BOD: N:P equal 100:5:1. The pH was between 7 to 7.5 and the temperature was between 18 deg C and 20 deg C. The dependent variables in each experiment were; the concentration of the influent, suspended solids contained in the aeration tank (3.15 to 11.17 g/l), and the waste water aeration period (2.9 to 123 hours). The experiment results amounting to 660 separate measurements were statistically analyzed with the use of the Least Squares

Method and calculated correlation factors were verified by the Students Test. These results were not interpreted either according to the Michaelis-Menten theory nor the two-phase hypothesis, but were generalized on the basis of the equation for a retardant reaction. It was concluded that under some conditions it is possible to use the activated sludge treatment even for very concentrated waste waters.

Keywords: activated sludge, sewage treatment, efficiency, mathematical models, chemical oxygen demand, kinetics, organic loading, waste water treatment, and fiber board.

SLUDGE ACTIVITY PARAMETERS AND THEIR APPLICATION TO TOXICITY MEASUREMENTS AND ACTIVATED SLUDGE

Florida Univ., Gainsville
J.W. Patterson, H.D. Putnam and P.L. Brezonik
Proceedings, Industrial Waste Conference, pages 127—154 (24th, May 6, 7, and 8, 1969)

The inadequancies of activated sludge operation control paramenters have long been recognized by waste treatment researchers and plant operators. Use of inappropriate monitoring methods for treatment unit degradation capabilities results in operation incompatible with both present legislative requirements for high quality effluent and economic requirements for high efficiency. The conventional methods of monitoring performance are discussed and the advantages and disadvantages of these measurements are presented. More specific biochemical parameters and their applicability to activated sludge systems under toxic stress are presented and discussed. The results of this study indicates: (1) the standard biomass and activity parameters (BOD, COD) are inadequate for current research and plant operation needs; (2) the application of biochemical concepts to measurement of activated sludge biomass and activity has advantages of sensitivity and specificity; (3) the application of any biochemical paramenter requires an understanding of the basic cellular mechanism involved; (4) effect of toxic agents may vary according to the food supply and physiological state of the organisms.

Keywords: waste water treatment, activated sludge, biochemical oxygen demand, chemical oxygen demand, legislation, effluents, laboratory tests, toxicity, mixed liquor volatile suspended solids, sludge volume index, sludge age, sludge yield, dehydrogenase activity, oxygen uptake rate and ATP analyses.

AN INTRODUCTORY STUDY OF REGULATION IN THE ACTIVATED SLUDGE PROCESS

N. Westberg
Water Research, Vol. 3, pages 613-621 (1969)

Based on a zero order kinetic expression with cell lysis and endogenuous terms, a dynamic model is developed for the completely mixed activated sludge process. Forcing the effluent substrate level to remain constant, the author determines the necessary control action for the return activated sludge rate. With in-phase sinusoidal variations of influent flow rate and substrate concentration, the manipulated variable, sludge recycle ratio was regulated so that the effluent substrate concentration remained constant. For perfect control, it is necessary to maintain an adequate supply of stored activated sludge. Any advanced regulation will require instruments continuously recording the organic load, oxygen concentrations, sludge concentrations, and flow rate of return activated sludge.

Keywords: automatic control, activated sludge, and manipulated variable

PERFORMANCE ANALYSIS OF AN ACTIVATED SLUDGE TREATMENT PLANT

Toronto Univ. (Ontario). Dept. of Civil Engineering
D.F. Carr and J. Ganczarczyk
University of Toronto, Department of Civil Engineering, Publication No. 71-600 (Feb. 1971)

The difficulty in accurately modeling or scaling various parameters in laboratory scale studies of the activated sludge process has led to attempts to obtain design data from full scale operating plants. It was determined that for this particular test, conducted at the Lakeview Sewage Treatment Plant near Toronto, the flow measurements and sampling procedures applied, as well as the scope of the analytical tests performed were insufficient to provide reliable evaluation of performance. Some interesting results from the study were: (1) simple statistical procedures may greatly improve the extent and quality of information to be drawn from operational data; (2) there seemed to be a total lack of correlation between final effluent BOD and the sludge loading factor; (3) little or no correlation existed between the SVI and the sludge loading factor; and (4) there was an increase of the SVI with an increase in the sludge return rate. The following conclusions were drawn from the study: (1) low plant effluent quality at the Lakeview Plant is due primarily to specific plant influent characteristics; (2) modification of the scope of plant metering and sampling procedures, and expansion of the analytical tests is essential to more fully characterize and explain the performance of the treatment facilities.

Keywords: activated sludge, evaluation, performance, statistical methods, analytical techniques, sampling, flow measurements, biochemical oxygen demand, dissolved oxygen, waste water treatment, sludge treatment, treatment facilities, sludge loading factor, sludge volume index, and mixed liquor suspended solids.

KINETIC ANALYSIS OF DATA FROM BIOLOGICAL SYSTEMS

Quirk, Lawler and Matusky, New York
R.L. Irvine, and D.J. Schaezler
Journal, Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 97, No. SA 4, pages 409—424 (August 1971)

Despite the fact that biological waste treatment facility design is extremely sensitive to proper selection of the reaction rate coefficient, none of the municipal works and few of the industrail plants now in operation considered reaction kinetics during design. Although flow variability component distribution, and gross concentrations in the waste stream at the full scale level may obviate results obtained from intensive laboratory data investigations for exact kinetic formulations, a laboratory data generation procedure is presented which will assure that the reactor designed will do the required job. This procedure involves: (1) characterization of the waste by repetitive acclimation; (2) determination of reaction rates by measuring and analyzing waste concentration BOD, TOC, etc., organism concentration, and oxygen uptake rates in a batch reactor; (3) design of a continuous flow bench sacle reactor; (4) after 1 to 4 weeks of operation of the C.F. bench reactor, remove a portion of the organisms and conduct batch reaction rate studies; and (5) design full scale unit on basis of reaction rate obtained in step 4. Care should then be exercised in selection of the correct operating scheme at the treatment plant to optimize efficiencies. Data from batch cultures fed glucose-mineral salts medium, domestic wastes, and domestic and industrial wastes are presented and analyzed as examples.

Keywords: kinetics, design data, laboratory tests, industrial wastes, municipal wastes, microorganisms, flow rate, dissolved oxygen, biochemical oxygen demand, activated sludge, waste water treatment, reaction rate coefficients and Michaelis-Menten equation.

OCCURRENCE OF FILAMENTOUS MICROORGANISMS IN ACTIVATED SLUDGE

G. J. Farquhar and W. C. Boyle
Wat. Pollut. Control Fed., 43, pages 779—798 (1971)

Using the techniques previously developed for identification, the ecology of filamentous microorganisms in activated sludge was investigated. Seventeen different types were found, and their source, extent of filamentous growth, sludge volume index, and mixed-liquor suspended solids concentration are shown in a table. Species of Thiothrix, Sphaerotilus, Toxothrix, Vitreoscilla, lactic-acid bacteria, and 2 unidentified forms grew extensively in a number of samples; other less-common filamentous organisms included Beggiatoa, Microscilla, Nocardia, and various septate fungi. Descriptions of all the microorganisms found are given in an appendix. Studies are being continued to determine the association of the various organisms with sludge bulking.

Keywords: filamentous, sludge volume index, activated sludge and microorganisms.

EFFECT OF HIGH SUBSTRATE CONCENTRATION AND CELL FEEDBACK ON KINETIC BEHAVIOUR OF HETEROGENEOUS POPULATIONS IN COMPLETELY-MIXED SYSTEMS

M. Ramanathan, and A.F. Gaudy
Biotechnol, Bioengng, 11, pages 207—237 (1969)

Growth kinetics in the complete mixing system of the activated-sludge process were studied, using heterogenous microbial populations of sewage origin. Observations were made under continuous-flow conditions with and without sludge recirculation. It was found that the Monod equation most accurately represented the relation between specific growth rate and substrate concentration, and that the recirculation of sludge even at a low cell concentration considerably improved coagulation and sedimentation.

Keywords: activated sludge, recycle ratio, improvement and coagulation.

RESIDUAL ORGANIC MATTER IN ACTIVATED-SLUDGE PROCESS EFFLUENTS, Vs, EFFECT OF THE INITIAL FOOD-TO-MICRO-ORGANISMS RATIO

J. Chudoba
Sb. vys. Sk. chem.-technol. Praze, Technol. Vod., 15, pages 23—34 (1969) (in English)

Using a batch activated-sludge system, experiments with glucose and a-alinine showed that the course of removal of COD and the amount of residual biologically undegradable organic matter in the effluent depended on the initial ratio of food: micro-organisms (F:M ratio). Increase of this ratio from 0.5 to 70 caused an increase in the amount of residual COD of about 1-4 per cent of the initial total oxygen demand. Possible causes of this phenomenon are considered, including the association of high F:M ratios with longer periods of aeration for substrate removal, higher percentages of oxidation of substrate, and higher percentages of synthesis of bacterial proteins.

Keywords: F:M ratio, activated sludge and COD.

ON THE DETENTION PERIOD OF SEWAGE IN THE ACTIVATED-SLUDGE PROCESS

W. Leithe
Gas- u. WassFach, 110, pages 598—599 (1969) (in German)

Discussing the importance of efficient sewage treatment processes, the author outlines the factors which should be considered when calculating the detention period for activated-sludge plants. Based on the accepted values defined as "Kehr's values" for the average detention period, the author divides these factors into three main groups, namely, the type, shape and volume of the aeration tank, the source of aeration and the types of stirrers and aeration systems used, and the distance the sewage has to travel from the point of entry at the sewage works to the point where it enters the tank. These 3 factors, although interdependent, are the vital link in the determination of the detention period. Data together with worked examples are given which also show how detention periods can be adjusted.

Keywords: efficiency, activated sludge, "Kehr's values," and sewage.

AUTOMATION OF AN ACTIVATED SLUDGE PLANT

V.H. Lewin and J.R. Hewley
Process Biochemistry (Feb. 1972)

The experiences and trials of the automation of the City of Oxford's activated sludge plant are described. Some of the conclusions reached are that the dissolved oxygen control system has proved adequately sensitive and the system provides a constant dissolved oxygen concentration with improved sludge characteristics and savings of at least 30% of the power costs. This economy varies, depending on load fluctuations, temperature, and the dissolved oxygen control settings. Experience indicated that dissolved oxygen sensor maintenance is not a problem; monthly washing and calibration are usually all that is required. Automatic operation of return activated sludge pumps provides a range of six rates of return, based on signals from the inlet flow recorders.

Keywords: automatic control, DO control, return activated sludge control, and economy of operation.

BIOCHEMICAL ENGINEERING ASPECTS OF THE ACTIVATED-SLUDGE PROCESS

C.D. Furness
Wat. Pollut. Control, Lond., 70, pages 528—532 (1971)

Studies on the kinetics of the activated-sludge process indicate that activated-sludge plants designed to incorporate elements of both completely-mixed and plug-flow systems will provide the most favorable conditions for oxidation of pollutants and activated-sludge condition. It is suggested that such systems should consist of up to 50 percent of the total aeration volume in the form of a completely mixed unit, followed by at least 2 other units arranged in series.

Keywords: plug flow, completely mixed, optimum and activated sludge.

EFFECT OF PROCESS VARIABLES ON SLUDGE FLOC FORMATION AND SETTLING CHARACTERISTICS

D.L. Ford and W.W. Eckenfelder
J. Wat. Pollut. Control Fed., 39, pages 1850—1859 (1967).

To obtain information on factors affecting sludge bulking in the activated-sludge process, laboratory aeration units were fed with brewery waste water, petrochemical waste water, or domestic sewage at different rates of loading. It was found that with increase in loading there was a change in microbial population, and in the most heavily loaded units 2 different forms of filamentous organism, which were mainly responsible for deterioration in the settleability of the sludge, appeared: one of these was a Sphaerotilus-type filament while the other had true fungal properties. Exposure of the sludge to anaerobic conditions for periods of 24 hours or more had an adverse effect on the filamentous organisms, although some did survive, and a period of anaerobiosis improved the settleability of the sludge without affecting its assimilative ability. Poor settleability was also observed in very lightly loaded units; in this case it was attributed to unoxidized fragments of the floc being broken up, with a consequent reduction in specific gravity. The bound-water content of a bulking sludge was much higher than that of an endogenous sludge, and it is thought that the bound-water phenomenon contributes to some extent to the settling characteristics of a sludge. In all cases there appeared to be a relation between oxygen uptake and the dehydrogenase activity of the mixed liquor, and both depended on the applied organic load.

Keywords: bulking, filamentous, loading, activated sludge and settleability.

RELATIONSHIP BETWEEN DISSOLVED OXYGEN CONCENTRATION AND OXYGEN UTILIZATION RATES IN ACTIVATED-SLUDGE WASTE TREATMENT

G.F. Bennett and L.L. Kempe
Chem. Engng Progr. Symp. Ser., 63, No. 78, pages 171—177 (1967)

In reviewing previous work on the conditions necessary to achieve maximal rates of decomposition of organic matter in the activated-sludge process (a bibliography of 39 references is provided), the authors emphasize the need for re-examination of previous conclusions in the light of experiments which showed that oxygen transfer data must take into account not only the oxygen available in solution but also the direct transfer from bubbles to cells (see also Wat. Pollut. Abstr., 1967, 40, Abstr. No. 553). Suggestions are made for further work on this mechanism of oxygen transfer and on its implications in the design of aeration systems and activated-sludge plants. The need for supplying maximal amounts of oxygen becomes most critical in new processes for the removal of phosphate and in processes requiring highly concentrated activated sludges.

Keywords: dissolved oxygen, activated sludge, bubbles and mass transfer.

THE IMPACT OF OILY MATERIALS ON ACTIVATED-SLUDGE SYSTEMS

Hydroscience, Inc. U.S. Wat. Qual. Office, Wat. Pollut. Control Res. Ser. 12050DSH 03/71, U.S. Govt Printing Office, Washington, D.C., 120 pages (1971), $1.25.

Laboratory experiments on the effect of oily compounds on the activated-sludge process showed that oils are adsorbed on the floc and degrade slowly, but if the loading rate is too high the oil accumulates on the sludge, causing a loss of density and impaired settling characteristics, although the ability of the microbial system to degrade other materials is not affected. The continuous feed of oil should not exceed 0.1 lb per lb of activated sludge per day.

Keywords: oily material, activated sludge, loading and bulking.

COMPUTER SIMULATIONS OF MICROBIAL POPULATION DYNAMICS IN THE ACTIVATED-SLUDGE PROCESS

C.R. Curds
Wat. Res., 5, pages 1049—1066 (1971).

A mathematical model of the activated-sludge process has been developed which considers the fate of bacteria which flocculate, those which do no flocculate, and 2 forms of ciliated protozoa, and computer simulation techniques have been used to study the population dynamics of these organisms in completely-mixed activated-sludge systems. At steady state the concentration of soluble substrate in the effluent is determined by the growth rate of the sludge bacteria, and the concentration of dispersed bacteria in the effluent is determined by the growth rate of ciliated protozoa.

Keywords: model, bacteria, flocculate, protozoa, population dynamics and dispersed bacteria.

EFFECTS OF SUBSTRATE CONCENTRATION AND ACTIVE BIOMASS ASSESSMENT ON THE KINETIES OF GLUCOSE UPTAKE BY A MIXED FILAMENTOUS POPULATION

W.H. McHarg
Thesis, Rice University, 120 pages (1971); Diss. Abstr., 32, B, pages 2201—2202 (1971).

Experiments have shown that the method used to determine active biomass concentration in aerobic waste treatment systems affects the prediction of reaction rate. The use of dry-weight measurements introduces an error, but better results are obtained using the substrate uptake rate, and a simple model based on maximal reaction rate as a measure of active organisms was found to predict correctly the transient response of the substrate concentration to changes in feed concentration.

Keywords: biomass, substrate uptake-rate, model transient response and reaction rate.

COMPUTER CONTROL ASPECTS OF AN ACTIVATED SLUDGE TREATMENT PLANT

Goodyear Tire and Rubber Co., Akron, Ohio
J. Neugroschl
IFAC, HAIFA, Symp, Comput Contr NAT Resources, Public Util. (Sept. 1967)

A mathematical steady state model was developed and the services of a computer employed for optimizing the process of pollution control by an automated activated sludge treatment plant. The goal of the study was to devise a plan for automatic control of the treatment plant by creating and maintaining optimum process conditions despite variations in influent flow and concentration; by (1) achieving optimal coordination of variables so as to remove the desired amount of waste, (2) reducing plant operating cost and (3) increasing protection against process failure through continued surveillance and monitoring. Average daily influent flow rates and biochemical concentrations (BOD) obtained from the Indianapolis treatment plant were used for a simulation of the control scheme.

Keywords: activated sludge, optimization, mathematical models, automatic control, water pollution control, waste water treatment, monitoring, computers, simulation and biochemical oxygen demand.

CONTROL OF A BIOLOGICAL TREATMENT PROCESS

J. Bernard
Effluent & Water Treatment Journal (April 1972)

Today, control of biological treatment plants is often desirable, and essential adjustments are usually based on routine observations and simple criteria. Biological purification and particularly the activated sludge process, has been thoroughly studied in the laboratories for the last 20 years. Basic biokinetic laws can be expressed in mathematical form to represent the development of an aerobic bacterial mass put in contact with pollution present in an aqueous medium. In the age of automation, the desire to control a sewage treatment plant is strong, not only on the basis of observations or analysis but on the basis of regular mathematical models that predict the development of the phenomena and ensure the necessary adjustment automatically. For the engineer working on an industrial scale, it is essential to know the limits of use of the mathematical models and the reliability of the available instruments.

Keywords: automatic control, analytical sensors, oxygen regulation, volumeter, turbidity meter, and cod meter.

RESPONSE OF ACTIVATED SLUDGE TO ORGANIC TRANSIENT LOADINGS

Associated Water and Air Resources Engineers, Inc., Nashville, Tenn.
E. Adams, Jr. and W. Eckenfelder, Jr.
Journal of the Sanitary Engineering Division, ASCE, Vol. 96, No. SA2, pages 333—352 (April 1970)

Three wastes; synthetic, industrial and domestic; were treated in laboratory activated sludge units. The units were subjected to transient organic loadings. Settling characteristics, effluent quality, oxygen requirements, and sludge build-up were monitored, and visual and microscopic evaluation made. Results showed the kinetic model, O = K sub L S sub E, which expresses removal as a function of growth limiting substrate remaining in solution, to apply satisfactorily to both steady and transient state conditions. The average removal rate coefficient, K sub L, appeared to increase under most transient conditions. This increase was possibly due to changes in organism population. The conventional oxygen utilization model was found to predict the oxygen requirements for steady as well as transient state conditions. The endogenous rate of oxygen uptake increased under transient conditions. The turbidity of the effluent increased with an increase in the average organic loading. Employing the synthetic substrate, it was found that activated sludge systems can tolerate up to three times the normal loading for 12 hours per day for several days without showing any significant increase of effluent soluble organic matter.

Keywords: activated sludge, organic loading, oxygen requirements, kinetics, domestic wastes, industrial wastes, turbidity, domestic wastes, waste water treatment, transient loading, endogenous respiration, synthetic waste and settling characteristics.

AUTOMATED ACTIVATED SLUDGE PLANTS WITH RESPIRATORY METABOLISM CONTROL

Omnium D'Assainissement, Paris (France)
P. Brouzes
Advances in Water Pollution Research, Proceedings Fourth International Conference on Water Pollution Research, held in Prague, Czechoslovakia, (April 21—25, 1969): London, Pergamon Press, Ltd, Sec. II, Paper 5 (Sept. 1968)

Sewage treatment plants have profited little from the numerous studies and the basic theories relating to the growth of cultures of micro-organisms. The main reason is probably the difficulty in controlling instantaneously the pollution load received at these plants. As a result, the energy consumption for oxygenation is excessive and the growth rate of the culture varies uncontrolled. The pollution load and its variations can be determined with very good approximation by treating the characteristic parameters by means of an analog computer. The energy consumption of oxygenation is reduced, since it corresponds at each moment to the actual pollution load. Control equipment varying in type from the simpler regulator to the analog computer, have been adopted for adjusting the two basic factors of air input and excess sludge removal. Excess sludge removal is achieved automatically in accordance with the desired operating conditions and the instantaneous pollution load, which the air input is adjusted so as to maintain a constant concentration of dissolved oxygen. Applying this control over the growth rate has enabled the power used to be reduced by 25% with a slight increase in the amount of BOD removal by the aeration plant.

Keywords: activated sludge, automation, control, metabolism, respiration, automatic control, control systems, growth rates, oxygen demand, oxygen requirements and auto-oxidation.

DETERMINATION OF ACTIVATED SLUDGE ACTIVITY—A POSSIBILITY OF CONTROLLING ACTIVATED SLUDGE PLANTS

Ruhrverband, Essen (West Germany)
W. Bucksteeg
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 83–94 (1966)

An activated sludge process can be regulated solely on the basis of organic load and sludge activity. In this way, sludge concentration, expressed as the activity can be adjusted for maximum efficiency during either maximum load, or the 24-hour average load. The activity of dehydrogenases of the activated sludge responds so fast that a relationship between the activity and the loading can be established over as short as a two hour period. Since activity, Y, is determined by the dry sludge mass, X, and the organic loading, and there is a direct relation between Y and the purification effect, A, then the purification efficency per unit volume is obtained by multiplying X by A. Therefore, because of the inter-relations, A, can be obtained when both X and Y are knows. Careful monitoring of X versus Y and the sludge volume index allows operators to quickly determine what the condition of the sludge inside the tank is, and hence an operator can prevent failure by spotting slugs of toxic material which may be entering the process.

Keywords: colorimetry, biodegradation, indicator, efficiency, purification, reduction, biochemical oxygen demand, activated sludge, sludge treatment, waste water treatment, 2-3-5-triphenyletrazolium chloride, extinction, red formzaone, damping intensity, empirical, mixed liquor and KMNC 4 demand.

THEORETICAL ANALYSIS OF ACTIVATED SLUDGE DYNAMICS

Clarkson of Technology, Pottsdam, N.Y. Dept. of Civil Engineering
C.R. Ott and R.H. Bogan
Journal of the Sanitary Engineering Division, American Society of Civil Engineers, Vol. 97, No. SA1, page 1–17. National Science Foundation Grant No. GK-180 (1971)

A computer simulation of the complete mixed activated sludge process was formulated to determine the response of the process to time variant BOD loading and amount of sludge recycle. Mass balance equations were derived for all processes concerned with the activated sludge mechanisms and these equations were then put into the computer. Perturbations to the system were provided either as step functions or time varying inputs. The effluent BOD was then monitored to determine the effect of the various inputs to the system. From the above simulation, it was determined that the effluent BOD concentration is two orders of magnitude more sensitive to variations in influent flow rate of BOD concentration than to variations in the sludge recycle rate. Also, the biological response rate was found to be very slow, and in the absence of adequate reserves of activated sludge, sludge recycle is relatively ineffective in controlling response of the process to rapid fluctuations in input conditions. Therefore, control of input flow rate and input BOD appear to provide the most effective means of process control, and BOD mass escapement can be most readily accomplished by minimizing flow fluctuations.

Keywords: mathematical models, computer models, simulation analysis, activated sludge, kinetics, organic loading, effluents, biochemical oxygen demand, model studies sludge, waste water treatment, step functions, transients, hydraulic loading, influent and suspended solids.

GENERIC FEED FORWARD CONTROL OF ACTIVATED SLUDGE

J. J. Davis, R.I. Kermode, and R.W.J. Brett

Journal of the Environmental Engineering Division, ASCE, Vol. 99, No. EE3, Proc. Paper 9803, pages 301—314 (June 1973)

Feed forward controllers for the completely mixed activated sludge process were developed and tested against the sludge growth rate models of five authors by computer simulation. Control was effective for all models and was shown to apply generally to growth models wherein specific growth rate is any function of substrate concentration. The control strategy involved manipulation of the recycle rate of return sludge. When the recycle rate was under proportional control from measurement of influent flow rate and derivative control from measurement of influent substrate concentration, soluble substrate in the effluent was minimized and stabilized. With recycle sludge storage, control was more effective.

Keywords: activated sludge process, digital simulation, environmental engineering, mathematical models, optimization, process control, quality control, and sewage treatment.

COMPUTER CONTROL ASPECTS OF AN ACTIVATED SLUDGE TREATMENT PLANT

Goodyear Tire and Rubber Co., Akron, Ohio
J. Neugroschl
IFAC, HAIFA, Symp, Comput Contr NAT Resources, Public Util (Sept. 1967)

A mathematical steady-state model was developed and the services of a computer employed for optimizing the process of pollution control by an automated activated sludge treatment plant. The goal of the study was to devise a plan for automatic control of the treatment plant by creating and maintaining optimum process conditions despite variations in influent flow and concentration. It was planned to accomplish this by: 1) achieving optimal coordination of variables so as to remove the desired amount of waste, 2) reducing plant operating costs and 3) increasing protection against process failure through continued surveillance and monitoring. The average daily influent flow rates and biochemical concentrations obtained from the Indianapolis treatment plant were used for a simulation of the control scheme.

Keywords: activated sludge, optimization, mathematical models, automatic control, water pollution control, wastewater treatment, monitoring, computers, simulation, and biochemical oxygen demand.

DIGITAL VS ANALOG MODELS

Oregon State Univ., Corvallis
L. N. Stone
In Use of Simulation in Water Research, SEMINAL WR 006.67, Oregon State Univ., pages 31—41 (Jan. 1967)

A comparison of present and future use of digital and analog computers for simulation, including digital differential analyzers and hybrid computers was given. The basis for discrete whole number operation of the digital computer using a memory and arithmetic unit was compared to the continuous operation of the analog computer which uses high gain amplifiers. The digital differential or incremental digital computer, and the hybrid computer which is a union of the analog and digital computers were discussed. Advantages and limitations of each type were presented. Examples of the speed and cost saving abilities of computers for simulation were given. Present and future capabilities for computer simulation in the United States, and Oregon State University in particular, were outlined.

Keywords: analog computers, digital computers, simulation analysis, analytical techniques, water resources development, analog models, comparative costs, computer models, economic efficiency, hybrid computers, digital differential analyzer and dynamic simulation.

ANALOG COMPUTER—A MODERN TOOL WATER POLLUTION CONTROL

Du Pont de Nemours (E. I.) and Co., Wilmington Del.
L. Falk
Proc, Amer Soc Civil Eng. Vol 88, No SA6, pages 31—59 (Nov 1962)

The applicability of digital and analog computers to the solution of water pollution mathematical models were compared. The suitability of the analog computer for the solution of differential equations and problems in kinetics not presently solvable by known mathematical techniques were described. Demonstration problems including first-order differential single and two-stage biochemical oxygen demand equations, the oxygen sag equation and the second order equation describing pollutant distribution in a tidal estuary were solved. A computer program was given for a variable cross section stream with multiple sources of organic pollution and heat loads, with continuously varying oxygen saturation values, deoxygenation and reaeration coefficients, and with continuously varying temperature corrections to those coefficients.

Keywords: analog computers, water pollution control, mathematical model, streamflow, computer programs, oxygen sag, biochemical oxygen demand, thermal pollution, dynamics, kinetics and differential equations.

MINICOMPUTERS AND WATER QUALITY SURVEILLANCE

Minneapolis-St. Paul Sanitary District, St. Paul, Minn.
J. J. Anderson
Proceedings of the National Symposium on Data and Instrumentation for Water Quality Management, Conference of State Sanitary Engineers and Wisconsin University (July 21-23, 1970), Madison, Wis, pages 420—429 (1970)

The newly developed minicomputer offers the opportunity for improvements in water quality data acquisition and monitoring. These devices are suitable for use with conventional parametric water quality monitoring stations and for use with other more complicated process stream analyzers. While automated data acquisition cannot be compared directly with historical manual methods, the costs for achieving similar objectives have reached similar orders of magnitude and are roughly comparable in certain cases. The typical minicomputer costs about $10,000, weighs about 50 pounds, and occupies a space of a little more than 2 cubic feet. These machines provide computing speeds measured in microseconds and computing and control capabilities equivalent to machines costing ten times as much only a few years ago. This may result in cost-effectiveness improvement of about 800 to 1.

Keywords: digital computers, data processing, hydrologic data, water quality, data collections, telemetry, instrumentation, sampling, monitoring, dissolved oxygen, automation, electrical conductance, data storage and retrieval, water management, systems analysis, mathematical models, simulation analysis and water quality data.

WASTE PLANT ADDS COMPUTER, SUBTRACTS AMMONIA

Anon
Engineering News-Record, 188(11), pages 26—27 (March 16, 1972)

The new computerized 30-mgd waste treatment plant being built by the Metropolitan Sanitary District of Greater Chicago is described. The plant will have a two-step aeration process to reduce ammonia to less than 2.5 ppm. Effluent levels of BOD and suspended solids, 4 ppm and 5 ppm, respectively, will also meet effluent standards of the Illinois Pollution Control Board. Two minicomputers will be installed in the plant: One to operate the process, the other as a backup and to make off-line engineering calculations and serve other functions.

Keywords: waste treatment plants, computers, aeration, ammonia, BOD, Metropolitan Sanitary District of Greater Chicago, and Salt Creek Water Reclamation Plant.

MODULAR MINI-COMPUTER PERMITS UNIT CONTROL

Chemical Engineering, Vol. 79, No. 4 pages (Feb. 21, 1972)

Control Automation Technology Company (CATCO) of Houston has developed a new, low-cost mini-computer called Unit Operations Controller (UOC) which combines a computer, digital display, recording modules, alarm modules, controllers, data display devices, manual operation features, and backup controls and power. It comes programmed to control a single unit e.g. a distillation column or chemical reactor. Costs range from $40,000 to $60,000 depending upon application. Up to 60 inputs can be handled, though 35-40 are normal. The computer can handle 20-30 control loops. Logging functions are provided, and up to 5 process chromatographic analyzers can be programmed. Temperature, pressure, and compositional variations for all orifice-type flow measurements are automatically compensated for. Nine recorders are provided, allowing an operator to switch from one service to another. Input variables can be integrated or summed over any time period up to 24 hr.

Keywords: computers, data processing, equipment, instrumentation, automatic control, automation, electronic equipment, research equipment, digital computers, unit operations controller, and recorders.

FEASIBILITY OF COMPUTER CONTROL OF WASTEWATER TREATMENT

H. D. Gilman
American Public Works, Associated, Chicago, Ill.
Copy available from GPC Sup Doc as EP 2.10:17090 Doy, $1.00; Microfiche From NTIS as PB-203 962, $0.95. Water Pollution Control Research Series, 77 pages (Dec. 1970)

A wastewater treatment study was conducted to: (1) analyze the advantages and limitations associated with the use of computers in the management and control of wastewater treatment facilities; (2) document potential applications and utilization procedures; and (3) recommend further research to achieve full computer implementation for wastewater treatment operations and associated management functions. Current problems and procedures were surveyed, including site visits to plants already automated to some extent. In addition, manufacturers were queried as to the availability of the monitoring and controlling equipment needed. Results indicated that management is indeed interested in automatic controls and computer application, but that both will come about largely on a piecemeal basis. Computer hardware and communication equipment is available and is already being utilized in many instances, but many on-line sensing instruments are not available.

Keywords: automatic control, digital computers, instrumentation, automation, data collections, sampling, monitoring, data transmission, operation and maintenance, personnel, technical feasibility, economic feasibility and waste water treatment.

TOWARD COMPUTER CONTROL OF WASTEWATER TREATMENT

Philadelphia Water Dept., Pa., and General Electric Co., Philadelphia, Pa.
C. F. Guarino, H.D. Gilman, M.D. Nelson and C.M. Koch
Presented at the 44th Annual Conference, Water Pollution Control Federation, San Francisco, California, 19 pages (Oct. 1971)

The various feasible approaches for automatic monitoring of the physical parameters that are significant in wastewater treatment and automatic central control of wastewater treatment plants are discussed. Computer control of wastewater treatment processes may be the only way to: satisfactorily cope with increasingly more stringent requirements of regulatory agencies, meet information requirements, optimize system operations, and combat today's rising operational costs. Computer process control requires: satisfactory sensors and instrumentation, communication equipment, electronic computers, and mathematical models.

COMPUTERS CONTROL OF WTP

The chief technological obstacles to implementation of plant automation are the need for process sensors and process control models. Sensor probes need to be developed to detect the required plant operation variables and to operate reliably in the hostile sewage environment. Studies are described of possible ways to make rapid determinations of BOD 5 by relating it to measurable parameters such as total organic carbon and total oxygen demand. Mathematical models of treatment processes are needed to convert acquired data into plant controls. Computer hardware and communication equipment present no limitations. Philadelphia is preparing to rebuild its three wastewater treatment plants using the most effective treatment methods available along with associated automated procedures. Their first attempt involves "near real time" digester automation at Philadelphia's northeast water pollution control plant. This will be a major step toward sewage treatment plant automation.

Keywords: automatic control, waste water treatment, digital computers, control systems, remote sensing, remote control, research and development, telemetry, electronic equipment, mathematical models, model studies and computers.

DIRECT DIGITAL CONTROL AT GRAND RAPIDS, MICHIGAN

Porter Monamee, and Seeley, Ann Arbor, Mich.
J. Curtis and M. Van Eyk
Preprint, 44th Annual Conference, Water Pollution Control Federation Session 2, No. 3, San Francisco, Calif., 8 pages (Oct. 3—8, 1971)

At current bond prices, it is financially attractive to spend up to $100,000 in capital cost in order to save the cost of one man-shift per day. If the proposed 50-25-25 (federal-state-local) financing of capital cost is achieved, the ratio of capital cost per man-shift changes to $400,000:1. To achieve this reduction in the number of man-shifts, a direct digital control system was designed for the city of Grand Rapids, Michigan's wastewater treatment facilities. The system would provide both monitoring and control of the plant. A dual channel technicon auto analyzer, a Perkin Elmer atomic absorption spectrophotometer, and a precision scientific COD analyzer were selected for monitoring of the waste stream, and they will input directly to the main computer for storage of the data. Control over the plant functions is accomplished through flow control and reduction of overflows from storms. Cost of the system was approximately $800,000, and the plant will tentatively be in full operation by early 1972.

Keywords: automatic control, digital computers, waste water treatment, treatment facilities, sampling, monitoring, flow control, electronic equipment, gates, valves, analytical techniques, water analysis, phosphate, dissolved oxygen, storm run-off, operation and maintenance, incineration, cost analysis, personnel, Michigan and Grand Rapids (Mich.).

CATAD SYSTEM CONTROLS FOR REGULATION OF COMBINED SEWAGE FLOWS

Municipality of Metropolitan Seattle, Wash.; and Metropolitan Engineers, Seattle, Wash.
C.V. Gibbs and S.M. Alexander.
Water and Wastes Eng, pages 46—49 (Aug. 1969)

COMPUTERS CONTROL OF WTP

The installation of a computer-augmented treatment and disposal (CATAD) system to utilize optimum storage within an existing municipal combined sewer system was described. The other objectives of CATAD were (1) to make available the maximum capacity of the interceptor for combined storm and sanitary flows in unseparated areas by utilizing the storage capability of trunk and interceptor sewers in separated areas; and (2) to control necessary overflows at selected locations so as to minimize harmful effects on marine life and public beaches. Control commands were generated internally by a computer under program control. A mathematical model was developed in order to implement a fully automatic control. The model incorporated elements of meteorology and hydrology including seasonal precipitation patterns and a real runoff characteristics. An analysis of the regulation of stormwater inflows by the use of trunk sewer storage established the operating rules required for effective utilization of the available storage.

Keywords: mathematical models, computer programs, sewers, storage capacity, storm runoff, sewage disposal, municipal wastes, automatic control, hydrologic properties, and combined sewers.

MANAGEMENT OF POLLUTION DATA USING MODERN TECHNIQUES

Minneapolis—St. Paul Sanitary District, Minneapolis, Minn.

R. L. Callery
Paper presented at the Annual Environmental Meeting of the American Society of Civil Engineers, Chicago, 18 pages (Oct. 15, 1969)

Modern techniques being used by the Minneapolis—St. Paul sanitary district in a project involving acquisition and management of water pollution data are described. The project was initiated to develop a system for remote dispatching of combined-sewer flows through the interceptor sewers in the Minneapolis—St. Paul area, and to improve the performance of sewer overflow regulators. Real-time water quality data are transmitted automatically by leased telephone wires, from transducers located at stations on the Mississippi River to a central station. Depth measurements and overflow regulator gate positions in trunk sewers and in the interceptor sewer system, together with readings from 9 rain gages, can be logged automatically in a central station, at almost any frequency desired. Analog signals, after being converted to digital form, are presented to the processor for logging, CR analysis, tabulation, correlation, or outputting. Programs supplied by the sanitary district can scan and log, separately, each of four different reports: (1) river quality monitor report, (2) overflow regulator report, (3) interceptor report and (4) rain report. The use of the STORET system, in-plant data logging, and automatic analysis of sewage quality using the Technicon Auto-Analyzer are described.

Keywords: data collection, data processing, data storage and retrieval, automation, instrumentation, remote control, computers, control systems, data transmission, telemetry, analytical techniques, regulated flow, remote sensing, flow control, sewers, outlets, urbanization and monitoring.

COMPUTER CONTROL OF WASTEWATER TREATMENT

C. F. Guarino, H. D. Gilman, M. D. Nelson, C. M. Koch
Journal Water Pollution Control Fed., 44, 1718 (1972)

Computers are now widely used for monitoring and reporting the operating conditions of wastewater treatment plants. The computers are now beginning to be used for the automated control of plant functions through the use of mathematical models that are abstract approximations of the actual physical processes. These models operate on the measured variables and calculate the proper values of the adjustable variables. The models can be used off-line in simulation or in closed-loop operation to actuate the controls required to achieve efficient operation.

Keywords: automation, computers, model, operation, simulation, and treatment plants.

A CONTINUOUS COAGULATION MONITOR FOR WATER CLARIFICATION CONTROL

Arkansas University, Fayetteville
C. McLaughlin, L. Weir, M. Bishop, and G. Brower
Paper presented at Arkansas Water Works and Pollution Control Conference and Short School, 40th, 21 pages (April 20, 1971)

Plant models with numerous intermediate modifications were constructed to aid in the development of a continuous coagulation monitor. The first model failed due to short-circuiting problems, dictating the construction of a second and third model consisting primarily of a flocculation chamber and a tube settler. A coagulant and alkalinity were added in solution form by means of a peristaltic pump and hydrodermic needles. Model 3 allowed four different systems of flocculation chambers and tube settlers to be dosed and operated simultaneously. This unit was field tested, and the alkalinity, turbidity, and pH of the raw water, the plant settled water, and the effluents from each of the four tubes were recorded. A fifth model was constructed using six channels to provide maximum variability. By identifying the effluent quality with some measurable parameter such as turbidity, a dynamic coagulation control can be achieved.

Keywords: flocculation, automatic control, monitoring, turbidity, colloids, zeta potential, bound water, sludge, hydrogen ion concentration, alkalinity, pressure, wastewater treatment, water purification, and coagulation.

PHYSICAL CONDITIONING OF ACTIVATED-SLUDGE FLOC

D. S. Parker, W. J. Kaufman, and D. Jenkins
J. Water Pollution Control Fed., 43, pages 1817—1833 (1971)

Studies have shown that the turbidity of effluents from activated-sludge plants is due to excessive floc breakup, caused by highly turbulent conditions in the aeration tank. The addition of a gently stirred flocculation unit between the aeration tank and final sedimentation tank provides an environment more conducive to aggregation and the incorporation of dispersed particles in the floc, giving a good-quality final effluent.

Keywords: clarification, flocculation, turbulence, activated sludge, and stirring.

STOICHIOMETRY OF COAGULATION

Harvard University, Cambridge, Mass.
W. Stumm and C. R. O'Melia
Journal of the American Water Works Association, Vol. 60, No. 5, pages 514—539 (May 1968)

Reaction steps in coagulation are: hydrolysis, the adsorption of the hydrolysis species to accomplish destabilization of the colloids, aggregation of destabilized particles by bridging, aggregation by particle transport and Van der Waa is forces, aging, and precipitation of the metal hydroxides. Some steps occur sequentially, some overlap and some occur concurrently. By careful choice of coagulant dosage, pH, and perhaps coagulant aids, the rates of pertinent chemical reactions may be adjusted so that particle transport controls the overall rate of aggregation. In many natural systems, particle transport is achieved by orthokinetic flocculation and therefore is influenced by the velocity gradient. More attention should be directed to the physical and chemical properties of flocs, density, shear strength, compressibility, and filterability. Trace quantities of impurities can have dramatic effects on the physical and chemical properties of the resulting flocs. The recent development of synthetic polyelectrolytes suggests many potentially beneficial effects on both the kinetics of floc formation and on the properties of the floc.

Keywords: water treatment, coagulation, flocculation, sedimentation, hydrolysis, adsorption, electrolytes, mixing, hydrogen ion concentration, filterability, polyelectrolytes, and velocity gradient.

CONCEPTS OF COAGULATION

Clemson University, S. C. Department of Environmental Systems Engineering
T. M. Keinath
Paper presented at New Developments in Textile Waste Treatment Seminar, College of Industrial Management and Textile Science. Clemson University (May 31—June 4, 1971)

A review of the coagulation theory was conducted to tie together the various theories being proposed at present. An analysis of the forces acting upon colloidal particles in a solvent demonstrated that the only parameter subject to outside control was particle size. Coagulation efficiency depends to a large extent on the magnitude of the charge which each colloid possesses. A colloid gathers counter ions about itself and becomes stabilized, so the object in coagulation is colloid destabilization, allowing colloids to come in contact and coalesce. The major models of colloid destabilization by: 1) indifferent electrolytes, 2) chemical bridging, and 3) coagulation with alum and iron are discussed in depth, considering varying physical and chemical conditions.

Keywords: coagulation, separation techniques, zeta potential, colloids, clays, bound water, cations, anions, sedimentation, chemical precipitation, iron, aluminum, wastewater treatment, reviews, literature review, hydrophobic, and hydrophilic.

COAGULANTS FOR WASTE WATER TREATMENT

Calgon Corp., Pittsburgh, Pa.
C. L. Fitsgerald, M. M. Clemens, and P. B. Reilly, Jr.
Chemical Engineering Progress, Vol. 66, No. 1, pages 36—40 (Jan. 1970)

The use of coagulants, whether of the conventional variety or the relatively new synthetic polymers, is a currently popular subject of conversation. Even though coagulants have been used for probably many centuries to stimulate flocculation, it is still impossible to determine conclusively why one flocculant may be effective at one time and suddenly become ineffective in the same or similar application. The methods of flocculation are discussed, and the deficiencies of metal salts and natural polymers as coagulant aids are presented. Synthetic polymers are listed and their applications discussed. Case histories of the use of coagulants are presented as examples of various applications. It is interesting to note that similar problems are not always solved in the same way. In any potential application, the major factors to be considered are: 1) solids size and electric charge, 2) the nature of oil waste (suspended or emulsified), 3) the polymer feed points, 4) the separation equipment design, and 5) the polymer structure. After consideration of these factors, bench-scale tests must be conducted to confirm, modify, or refute the proposed treatment. Only then can full-scale plant application provide the final proof.

Keywords: wastewater treatment, effluent quality, coagulation, industrial wastes, flocculation, aluminum, iron, clays, gels, design, oil, pulp wastes, cation adsorption, anion adsorption, coagulants, polymers, metal salts, vegetable gums, and feed points.

DEFINED VELOCITY GRADIENT MODEL FLOCCULATOR

University College, London (England)
F. A. VanDuuren

Journal of the Sanitary Engineering Division, American Society of Civil Engineers, Vol. 94, No. SA4, Proceedings Paper 6076, pages 671—682 (Aug. 1968)

Orthokinetic flocculation is the most important engineering process in removing from water mineral and biological particles up to the size of bacteria. Flocculation is effected by the collision of particles, which occurs when velocity gradients exist within a flow. Hence, the study of flocculation requires devices for which shear in the flow can be determined. With this objective, design criteria are outlined and the theoretical basis given for a velocity gradient flocculator. A coaxial cylinder (horizontally mounted) couette device that has been developed is described. The advantage of horizontal mounting of cylinders is to limit sedimentation. This flocculator can be used to apply a desired velocity gradient to particle suspension in order to study various aspects of flocculation. The device behaves hydraulically in that it results in a predominantly two-dimensional flow for a wide range of particle coagulant concentrations. The floc-flow patterns observed in flocculation tests with quartzite particles and alum are described.

Keywords: flocculation, shear flow, laminar flow, sedimentation, suspension, design criteria, mathematical studies, bacteria, hydraulics, diffusion, flocculator, velocity gradient, coaxial cylinders, Ritchie device, annulus two-dimensional flow, flow stability, centripetal acceleration, theoretical analysis, design desiderata, synchronous electric motor, and couette model flocculator.

THE EFFECT OF NITROGEN AND PHOSPHORUS COMPOUNDS ON ONE OF THE MICROORGANISMS RESPONSIBLE FOR SLUDGE BULKING

Toronto University (Ontario)
P. H. Jones

Proceedings of Industrial Waste Conference, 20, Vol. XLIX, No. 4, pages 297—315 (July 1965)

The term "sludge bulking" refers to the development of poor settling properties in sludge and is defined as a biophysical response to some upset in the ecological balance of a mixed population of microorganisms. This phenomenon commonly occurs in municipal sewage-treatment

plants where sewage rich in carbohydrates is found. Since such sewage is usually deficient in nitrogen and phosphorus, a study was undertaken to ascertain whether the microorganisms might actually become dominant due to the indirect effect of increasing BOD/N or BOD/P ratios. Evidence was sought to support the contention that a variety of filamentous microorganisms, including Geotrichum candidum, are closely associated with the sludge bulking phenomenon. Studies were done on a cross-section of organic and inorganic nitrogen sources when combined with a series of different carbon sources. Tests were also made to show the effect of allowing the concentration of inorganic phosphorus in an otherwise adequate medium. Several different phosphorus ratios were studied. Evidence obtained in these tests showed that in phosphorous or nitrogen deficient wastes, Geotrichum hold a competitive advantage over the microbial population as a whole.

Keywords: sludge treatment, aquatic fungi, carbohydrates, molds, nitrogen, phosphorus, analytical techniques, activated sludge, nutrient requirements, water pollution sources, wastewater treatment, sludge bulking, Geotrichum candidum, and nitrogen sources.

COAGULATION CONTROL

Neptune Microfloc, Inc., Corvallis, Oregon
W. R. Conley and R. H. Evers
Journal of the American Water Works Association, Vol. 60, No. 2, pages 165—174 (Feb. 1968)

The automatic coagulation control system in use at a 1-mgd water treatment plant in Mill City, Oregon, is described. Of all the methods of monitoring coagulation in use today (electrophoresis, jar tests, streaming current, and pilot filters), only the pilot filter system measures directly the variable of interest to the plant—the filtered water turbidity. The pilot system provides an early warning of improper coagulation conditions. It allows quick and accurate evaluation of coagulant dosage changes. Coagulation control can be maintained even under rapidly changing raw water conditions.

Keywords: water treatment, coagulation, filters, filtration, automatic control, turbidity, and monitoring.

WATER QUALITY CONTROL WITH SYNTHETIC POLYMERIC FLOCCULANTS

Connecticut University, Storrs, Institute of Water Resources
J. K. Dixon
Available from NTIS as PB-195 983, $3.00 in paper copy, $0.95 in microfiche. Technical Completion Report, 4 pages (Nov. 1970)

Studies have been made of the flocculation of silicon algae and bacteria by means of low concentrations of synthetic polymers. The effects of polymer molecular weight and structure have been emphasized, using the silica, and pure cultures of green algae and E. coli under a variety of conditions of pH and colloid concentration. Filtration rate, light transmission, and electrophoretic mobility have been employed to measure the degree of flocculation. Non-ionic and anionic polymers did not produce flocculation, but cationic polyethyleneimines were effective at concentrations of 0.1 to 100 ppm, the optimum being dependent on pH, colloid concentration, and molecular weights above about 2000. The algae required a solution concentration of polymer that was some 30 to 500 times higher than did the bacteria and silica, respectively. Two types of polyethyleneimine polymer, tagged with radioactive C14, were prepared which flocculated the three kinds of colloids in the same way as untagged polymers. In the region where flocculation was optimum, the concentrations of polymer adsorbed on the colloid surfaces stood in roughly the ratio of 1:10:200 for silica, E. coli and algae, respectively. Poor flocculation efficiency was not to be associated with low adsorption, but to specific polymer-surface interactions that reduced the efficiency of the adsorbed polymer. The results have been shown to conform with current theories of flocculation of other colloids. They should assist in attaining better water quality control by use of the synthetic polymers in numerous practical operations.

Keywords: flocculation, filtration, electrophoresis, settling, algae, silica, bacteria, water pollution control, wastewater treatment, polyacrylamide, and polyethylenimine.

EXPERIMENTAL EVALUATION OF OPERATING VARIABLES IN CONTACT FLOCCULATION

Engineering-Science, Inc., Oakland, Calif.
T. G. Shea, W. E. Gates, and Y. A. Argaman
Journal of American Water Works Association, Vol. 63, No. 1, pages 41—48 (Jan. 1971)

Contact flocculation is a water clarification process whereby the raw water is applied directly to a filter without prior clarification by sedimentation. It is designed to bring about flocculation, coagulation, and solids separation directly in the filter bed. Fine-to-coarse filter beds conventionally used are not adequate for contact flocculation because the fine top layers remove most of the incoming materials. Coarse-to-fine filtration of such beds can be accomplished only by upflow filtration. An alternate is the use of multi-media filters, the upper layers of coarse particles of low density and lower layers of fine particles of high density. Contact flocculation is a technically feasible process for water clarification and can compete favorably with the conventional clarification system of flocculation, sedimentation, and filtration when the suspended solids concentration in the raw water is low. Among the three types of media studied, the best performance was obtained with the coarse and uniform dual media. Lower performance was obtained with the fine well-graded dual media bed. The least desirable performance was provided by the single media sand filter. The polyelectrolyte Cat-Floc was found superior to alum in both technical and economic repeats. Early floc breakthrough occurred in the coarse filters when a low polyelectrolyte dose was applied.

Keywords: water treatment, coagulation, flocculation, sedimentation, filtration, suspended load, electrolyte, alum compounds, filters, contact flocculation, multi-media filters, and pilot-plant.

STATE OF THE ART OF COAGULATION, MECHANISMS AND STOICHIOMETRY

American Water Works Association, New York, Research Committee on Coagulation
Journal of American Water Works Association, Vol. 63, No. 2, pages 99—108 (Feb. 1971)

Historically, two approaches have been advanced to explain the basic mechanism involved in the stability and instability of colloid systems. The chemical theory assumes that colloids are aggregates of definite chemical structural units and emphasizes specific chemical interactions between the coagulant and the colloids. Coagulation is the result of a precipitation of insoluble complexes formed by the chemical interaction. The physical or double-layer theory emphasizes the importance of the electrical double-layers surrounding the colloidal particles in the solution and the effects of counter-ion adsorption and zeta-potential reduction in the destabilization of colloidal systems. The two theories may appear to be contradictory, but they are not mutually exclusive. Both mechanisms must be employed in understanding and control of colloid stability-instability. The two mechanisms are discussed, the physical mechanism under headings of electrical double-layers, electrokinetic or zeta potential, colloidal-interactions, and coagulation kinetics; the chemical mechanism under metal ions, polyelectrolytes, configuration in solution, adsorption from solution, configuration at the solid-liquid interface, and flocculation kinetics. Research needs are indicated under four classes: surface properties of colloids, specific surface adsorption, coagulation kinetics, and metal-ion complexes.

Keywords: water treatment, coagulation, flocculation, stability, colloids, zeta potential, wastewater treatment, chemical reactions, kinetics, electrochemistry, ions, adsorption, destabilization, electrical double-layers, and colloidal surface properties.

ELECTROPHORETIC STUDIES OF TURBIDITY REMOVAL BY COAGULATION WITH ALUMINUM SULFATE

Florida University, Gainesville, Department of Chemistry
A. P. Black and S. A. Hannah
Journal of the American Water Works Association, Vol. 53, No. 4, pages 438—452 (April 1961)

The relationship of particle zeta potential and coagulation in dilute clay suspensions was investigated as alum dosage, and pH were varied. In addition, the effects of polyelectrolyte coagulant aids on zeta potential and on coagulation were determined. The polyelectrolyte series utilizes eight coagulant aids, including six commercial products, starch, and caustic starch. An amount of alum equivalent to several times the base-exchange capacity of the clay suspension was required to neutralize the particle charge. Clarification was best in the pH range 7.5—8.5 where the particles were negative, rather than at pH values where the particle charge had been neutralized. All eight coagulant aids used with alum could be made to improve or inhibit coagulation by the selection of dosages of alum and aid. As in the coagulation at different pH values, final particle charges could not be correlated with residual turbidities.

Keywords: water treatment, electrophoresis, electrolytes, clays, turbidity, coagulation, zeta potential, hydrogen ion concentration, aluminum sulfate, and coagulant aid.

POLYMER FLOCCULATION KINETICS OF DILUTE COLLOIDAL SUSPENSIONS

California Institute of Technology, Pasadena, W. M. Keck Lab. of Environmental Health Engineering
F. B. Birkner and J. J. Morgan
Journal of the American Water Works Association, Vol. 60, No. 2, pages 175—191 (Feb. 1968)

Experiments conducted under turbulent flow conditions in a stirred-tank-type reactor demonstrated that the flocculation process is the rate-controlling step in polymer destabilization. At optimum polymer dosage, the apparent rate of decrease in total particle concentration can be represented by a first-order reaction equation. Particle aggregation proceeds at a faster rate when coagulation is induced by sodium chloride than when a polyelectrolyte is used. Also, salt-coagulated systems appear to be more resistant to deflocculation than polymer-flocculated systems. Maximum particle removal efficiency occurred at the optimum polymer dosage. However, flocculation did proceed to a limited extent when either overdosed or underdosed polymer conditions prevailed. Particle removal efficiency was greater with the overdosed polymer condition, rather than the underdosed condition, only when the systems were subjected to intense agitation. When an insufficient amount of polymer was present, the extent of flocculation was severely restricted by the limited number of polymer bridges that could be formed. Comparison of optical density and total particle concentration on settled water revealed no obvious correlation between these two parameters, primarily because the optical properties are dependent on the size of particles as well as number.

Keywords: water treatment, colloids, electrolytes, coagulation, sedimentation, filtration, and destabilization.

PLANT-SCALE POLYELECTROLYTE TREATMENT OF WASTEWATER USING STREAMING CURRENT CONTROL

Robert S. Kerr Water Research Center, Ada, Okla.; Dow Chemical Co., Midland, Mich.; West Virginia University, Morgantown, W. Va.; and Illinois Institute of Technology, Chicago, Ill.
C. P. Priesing, R. V. Wolfe, W. A. Sack, and S. Kelman
Journal Water Pollution Control Federation, Vol. 41, No. 8, Part 1, pages 1524—1532 (Aug. 1969)

A determination is made on the applicability of an automated streaming current detector (SCD) to control the feeding of a polyelectrolyte in a full-scale operation and, specifically, the degree of treatment attainable with a flocculant (the Dow Chemical Company's Purifloc ® C31) at various preselected SCD readings. A 450-gal automatic dilution and storage system is used for flocculator feed at a 50-mgd chemical coagulation plant with separate sludge digestion. The SCD senses the waste H_2O flow and transmits an electrical signal to a variable speed drive unit that drives the polyelectrolyte solution delivery pumps. The raw wastewater samples are analyzed for carbon concentration and BOD. Effluents containing 50 mg/l of BOD and 42 mg/l of carbon were obtained at a streaming current reading of 0. Sampling techniques used in the study are explained. Lower doses of flocculant are required in a full-scale plant than in the laboratory studies.

Keywords: wastewater treatment, sludge digestion, biochemical oxygen demand (BOD), feeding rate, sampling, flocculation, instrumentation, polyelectrolytes, streaming current, detector, automatic, wastewater sample system, feeding system, and hydraulic flow.

APPLICATION OF THE STREAMING CURRENT DETECTOR TO THE CONTINUOUS MEASUREMENT AND CONTROL OF COLLOIDAL SYSTEMS

Leeds and Northrup Co., North Wales, Pa.
B. J. Galetti
Water Quality Instrumentation, 1, pages 126–141 (Eng) (1972)

Evidence confirms the utility of a streaming current detector in many separation processes where adjustment of the solution charge is required. The instrument's value is as a device to continuously monitor dispersions and to initiate automatic corrective action. Precise control of these processes results in uniform and reliable operation with significant cost savings.

Keywords: streaming current detector, automatic control, clarification, and reliable operation.

USE OF POLYELECTROLYTE COAGULANTS TO ENHANCE SETTLING CHARACTERISTICS OF ACTIVATED SLUDGE

Weston (Roy F.), Inc., Newtown Square, Pa.
J. F. H. Walker and J. H. Dougherty
Proceedings, Industrial Waste Conference, 22nd (May 2, 3, 4, 1967), Purdue University, Vol. LII, No. 3, pages 715–723 (July 1968)

Studies were conducted on 3 anionic, 6 cationic and 3 nonionic polyelectrolyte coagulants to determine their effect as coagulant aids in settling and flocculation of activated sludge. The BOD reaction rates were significantly suppressed with certain polyelectrolyte materials studied and oxygen utilization rates were not significantly affected. No one type of polyelectrolyte was found to be universally effective in increasing the agglomeration and settling rate of activated sludge but, on occasion, sufficient gas entrapment might occur to result in the flotation of sludge flocs. It was determined that polyelectrolyte coagulant aids could be useful in the solution of the settling problems encountered in many waste water treatment plants.

Keywords: coagulation, activated sludge, sedimentation, flocculation, biochemical oxygen demand, flotation, waste water treatment, electrolytes, settling velocity, polyelectrolytes, coagulants, utilization rates, anionic, cationic, nonionic and agglomeration.

CONTACT STABILIZATION

A MATHEMATICAL MODEL FOR CONTACT STABILIZATION-MODIFICATION OF THE ACTIVATED SLUDGE PROCESS

Toronto University (Ontario)
P.H. Jones

Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1 1970)

Contact stabilization modification involves the mixing of a well-conditioned activate sludge with fresh, unsettled, raw wastewater for a brief period. During this period of contact, the sludge removes organic and inorganic pollutants by several mechanisms. The major mechanisms involved are absorption, adsorption, and simple physical entrapment. Removal is extremely rapid but the organic material is not stabilized in this reactor. The initial contact is therefore followed by a solid-liquid separation (usually by settling), and the sludge containing the unstable organics is then admitted to a sludge re-aeration tank. It is hypothesized that the three removal mechanisms occur simultaneously and are described by various mathematical models. Adsorption and physical entrapment are physical reactions and a function of: 1) the particulate material, 2) velocity gradient, 3) mixing operation, and 4) concentration of solids in the form of floc. The reaction is assumed to obey a first order differential equation. Absorption is assumed to obey the same equation as the growth of microorganisms. Another equation is defined for the hydrolysis of the material. A computer program was written incorporating these variables and validated through the use of laboratory tests. A mathematical model was postulated and the calculated and observed curves matched quite closely. The complete computer program is presented.

Keywords: mathematical model, activated sludge, sewage treatment, wastewater treatment, absorption, hydrolysis, computer programs, contact stabilization, and laboratory studies.

REMOVAL OF ORGANIC COLLOIDS BY MICROFLOTATION

Clarkson College of Technology, Potsdam, N.Y., and Ohio State University, Columbus, Water Resources Center
E.A. Cassell, A.J. Rubin, H.B. LaFever, and E. Matijevic
Water Wastes Engr, Vol. 6, No. 5, pages C.7—C.10 (May 1969)

The application of microflotation or foam separation to the treatment of wastewaters seems practical in many water renovation applications at present. Microflotation can replace coagulation-sedimentation and be followed by the new high-rate filters. This unit would be compact because of the rapid removal of the color- and turbidity-causing particles. It is also a rapid and efficient method of removing bacteria. Research is needed to better understand the effects of various types of dispersions, electrolytes, and/or polyelectrolytes. Test data for the removal of the colloidal materials by foam separation is presented.

Keywords: foam separation, model studies, E. coli, electrolytes, tertiary treatment, microflotation, color removal, turbidity removal, and bacteria removal.

DISSOLVED-AIR TREATMENT OF COMBINED SEWER OVERFLOWS, A DEMONSTRATION PROJECT OF A PROTOTYPE TREATMENT PLANT DESIGNED TO TREAT WASTES FOUND AT A COMBINED SEWER OVERFLOW

Rhodes Technology Corporation, Houston, Texas
Available from the Clearinghouse as PB-189 775, $3.00 in paper copy, $0.65 in microfiche.
Federal Water Pollution Control Administration, Research Series, WP20-17, 216 pages (Jan. 1970)

A dissolved-air flotation system was evaluated for primary treatment of combined sewer overflows. The major pieces of component equipment were a gyratory screen, hydrocyclones, an air-dissolving tank, and a flotation cell. The principal aspects investigated were: 1) the performance of the system during rain events and dry periods, 2) the evaluation of individual components, 3) the capital costs and operating costs for utilizing a flotation system for various-size combined sewage overflows, 4) the adaptability of the system for automation and use in a remote location, and 5) the ability of the system to treat intermittent and highly variable flows from combined sewage systems. Some chemical aids to flocculation were also tested. The system performed comparably to conventional clarifiers. It appears that dissolved-air flotation systems would be economical for handling combined sewer overflows up to 8 mgd. Automation of dissolved-air flotation systems appears possible with conventional control equipment. Chemical aids to flocculation appear to have promise that warrants further study. The system was unique in that all liquid flow passed directly through the air-dissolving tank with no recycle. Domestic sewage was studied in lieu of combined sewage during periods of no rain. Conclusions, recommendations, and benefit-cost relationships are presented in the report. A description of the demonstration plant and of the drainage area served by the flotation system is appended.

Keywords: combined sewers, storm water, overflows, dissolved-air flotation, infiltration, treatment methods, primary treatment, flocculant aide, suspended solids, and storm runoff.

OZONE TREATMENT OF SECONDARY EFFLUENTS FROM WASTE-WATER TREATMENT PLANTS

Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio
D.A. Huibers, R. McNabney and A. Halfon
Rep. submitted to fulfill contract between Fed. Water Pollut. Contr. Admin. and Air Reduction Co, Inc., Robert A. Taft Water Res Center Rep. No. TWRC-4, Fed. Water Pollut. Contr. Admin. Advance Waste Treat Res Lab 62 pages (April 9, 1969)

Ozone effectively lowers the chemical oxygen demand and total organic carbon content of effluents from wastewater treatment plants. It removes odors and color from water and destroys pathogenic organisms. Tertiary treatment with ozone has the potential of an automated, trouble-free operation with low maintenance. An efficient contacting process and a prelimenary evaluation of its economics were investigated. Ozonation was first studied by low-shear countercurrent contracting in an 18-ft column packed with Raschig rings. Later it was found that the rates of COD and TOC removal could be considerably increased by high-shear contacting using a turbine agitator. The optimum treatment of secondary effluent with ozone required multi-stage concurrent contacting. A six-stage system was simulated by mixing through the 18-ft packed tower. Overall efficiences as high as 90% were obtained. The estimated treatment cost is 7.7 cents/1000 gal to reduce the COD from 35 mg/l to 15 mg/l assuming an 80% ozone-utilization efficiency in a 10 mgd plant. This is about equal to the estimated cost for treatment with activated carbon. Chemical clarification of the secondary effluent prior to treatment with ozone would reduce ozone consumption and result in a lower final COD and TOC.

Keywords: tertiary treatment, ozone, oxidation, chemical reactions, pilot plants, oxygen demand, chemical oxygen demand, organic matter, nutrients, costs and ozonation.

KINETICS OF WASTEWATER CHLORINATION IN CONTINUOUS FLOW PROCESSES

California Univ., Berkeley; and California State Health Dept.
R.E. Selleck, H.F. Collins and G. White
Eight International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

The effect of reactor mixing on the process performance of wastewater chlorination was studied in this investigation for the purpose of obtaining information which can be used to improve the performance of the process as well as to aid in its control. The significance of mixing in terms of process performance is illustrated. In one case an aqueous solution of gaseous chlorine was added to the head of a tubular reactor and in the second case directly to a completely backmixed tank reactor. The residence time in the tubular reactor was only 0.12 minutes while the mean residence time in the backmixed tank was 37.5 minutes. The overkill effected by the two methods of chlorination were radically different. The overkill was more than one order of magnitude greater than chlorine when applied to the tubular reactor. It is concluded from this study that the rate of kill appears to be independent of all factors except amperometric chlorine residual concentration and contact time (and possible temperature).

It appears that some bactericidal action takes place as long as any detectable amperometric residual exists in the chlorinated waste water. The results also indicate that the bactericidal potential of the amperometric chlorine residual decreased with time. This indicated that the residual is composed of a number of different species of chlorine compounds which tend to cascade with time toward a less reactive species.

Keywords: kinetics, chlorination, waste water treatment, sewage treatment, flows, mixing, coliforms, mathematical models, ammonia, tube, tube reactor and chlorine demand.

BOD REDUCTION BY CHLORINATION

Florida Univ., Gainesville. Dept. of Bioenvironmental Engineering
R.H. Susag
Journal of the Water Pollution Control Federation, Vol. 40, No. 11, Part 2, pages R434—R444 (Nov 1968)

The effect of chlorination on deoxygenation behavior was investigated in waste waters and treatment process effluents. Reduction in BOD values was observed on chlorination. What was more significant, however, was the retardation in BOD exertion as demonstrated by a reduction in the deoxygenation constant K. Several tests were conducted employing raw waste water as the test substrate with chlorine dosages varying from 5 to 40 mg/l and chlorine contact time varying from 30 to 60 minutes. At a chlorine dose of 10 mg/l the K value was determined to be 0.143 while the nonchlorinated sample showed 0.195. A comparison between effluent chlorination and additional treatment processes indicated that annual costs for effluent chlorination would be only 8 to 40% of the costs for the additional treatment providing operation periods totalled not more than 52 days annually. The extremely high daily operation costs indicated that the use of this method is limited as a process operation to a non-regular basis. This example indicates that effluent chlorination has a practical application when employed as a supplement to reasonable waste water treatment for the maintenance of desired dissolved oxygen levels at adverse receiving river dilution conditions.

Keywords: biochemical oxygen demand, chlorination, aerobic treatment, chemical oxygen demand, costs, dissolved oxygen, waste water treatment, effluents and deoxygenation constant.

CLOSED LOOP CHLORINATION FOR WASTE WATERS

Metcalf and Eddy, Inc., Boston, Mass.
A.A. Thomas and W.H. Brown
Journal of the Water Pollution Control Federation, Vol. 40, No. 4, pages 684-688 (April 1968)

Closed loop chlorination provides a relatively inexpensive method by which all treatment plants can provide effective chlorination. Hardware to provide chlorination control by flow has been available and in satisfactory use for many years. It costs approximately $5,000 and requires maintenance as does any instrumentation equipment. These instruments can replace four men required to measure chlorine residuals around the clock and actually compute continuous chlorine residuals which can be recorded. The information from chlorine residual instruments can be returned to controls which change the rate of chlorine feed to the waste water. This system of continually determining chlorine residual and continually adjusting the rate of chlorine feed to get a predetermined chlorine residual is called closed loop chlorination. The loop is formed by feeding back upstream control information. The future efficiency of treatment expected will make accurate manual control almost impossible, leaving closed loop chlorination the answer for economical and effective chlorination of treated and untreated waste waters.

Keywords: chlorination, automatic control, waste water treatment, costs, design, equipment, chlorine, coliforms, closed loop chlorination and dosage, residual.

CHLORINATION AND DISINFECTION—THE STATE OF THE ART

American Water Works Association, New York, Research Committee on Disinfection and Chlorination
J. Morris
Journal of American Water Works Association, Vol. 63, No. 12 pages 769—774 (Dec. 1971)

Research on engineering aspects of disinfection is badly needed. Particularly desirable are additional fundamental studies on ozone and chlorine dioxide with varied conditions of pH, temperature, and other aspects of water quality. The critical research needs are demonstration-scale studies of the efficacy of possible modes of disinfection. Such research requires assessment techniques that are considerably more sensitive and rigorous than the coliform tests now used. Tools for the measurement of excellent bacterial quality are necessary. Water utilities must be willing to employ persons qualified, both in spirit and training, to do quality research, and to provide them with time, facilities, and equipment for experimental studies. Appropriate collaboration between water utilities and universitites, governmental laboratories, or consulting firms may be one method by which needed facilities and personnel can be brought together. Certainly a willingness for state or federal funding of research is an essential in the water treatment area as in the waste treatment area. Special emphasis should be given to relative efficiency of single dosing versus multiple doses and to the use of multiple agents such as combinations of ozone and chlorine.

Keywords: public health, water quality, sanitary engineering, water treatment, disinfection, research chlorine, ozone and chlorine dioxide.

AUTOMATION OF CHLORINATION PLANTS FOR THE DISINFECTION OF POTABLE AND WASTE WATERS

P.V. Opov and M. Evetanov
Trud. nauchnoizsled, Inst. Vodosnab. Kanaliz. sanit. Teckh., Sofia, 5, pages 5—26 (1970) (in Bulgarian, English summary).

From a detailed survey of problems encountered in chlorination plants in Bulgaria, recommendations are made on the automation of the plants and the necessary schemes and equipment are described with illustrations and flow diagrams.

Keywords: chlorination, automation and disinfection

CLOSED LOOP CHLORINATION CONTROL

Fischer and Porter Co., Watminster, Pa.
L.J. Carroll
Journal Sanitary Engineering Division, American Society of Civil Engineers, Vol. 92, No. SA2, pages 51—57 (April 1966)

Chlorination control is discussed. Advancements in instrumentation have been made. Residual analyzers are now playing a major role in the efficient operation of both existing and newly constructed water treatment plants. To better evaluate these developments, a number of factors should be considered. Of prime importance would be the initial benefits of residual control. Equally relevant is its economic justification. Various aspects of system design are explored with particular emphasis placed on the areas of major concern, such as control loop lag time, chlorinator sizing, and proportional control. Problems inherent to water and sewage treatment are studied and recommendations for improvement are proposed. Specific cases are cited and described in some detail to illustrate these points.

Keywords: water treatment, sanitary engineering, chlorination, automation, design, analysis, control and closed-loop control.

QUALITY VERSUS RESIDUAL CHLORINE

Public Health Service, Cincinnati, Ohio. Control Technology Branch
W. Buclow
Journal American Water Works Association, Vol. 63, No. 1 (Jan 1971)

This paper deals with how much, what level of, and the proper surveillance of chlorine residual. A review of some literature which shows the influence of chlorine residual on bacteriological quality in distribution systems as well as the sampling practice in Europe is presented. Chlorine residual in 1966—1967 in Cincinnati, Ohio was maintained at .85 plus or minus .2 mg/l. But in 1969—1970 this was increased to 2 mg/l with 80% as free chlorine. Tabulated results for this period show no appreciable variations in the bacteriological quality of the water and it shows that a change from combined to free chlorine residual and increase in residual concentration reduced the monthly average coliform counts. Study of the bacteriological quality of the distributed water by the use of various systems as related to chlorine practice is presented with supporting figures and tables. It is concluded from that study that surface, spring and raw well water sources need to be chlorinated if coliform was detected in the distribution system and not detected in the raw water. A presentation of this sample procedure and findings for the Cincinnati water system with illustrative drawings and tables is included. The data collected from that system support the suggestion that the bacteriological samples should be collected from known problem areas in reservoirs, dead ends and the periphery of the system.

Keywords: chlorine, coliform, water distribution systems, turbidity, clarification, groundwaters, surface waters, springs, and water treatment.

EFFECT OF ELECTROLYSIS ON THE DISINFECTION OF WASTE WATERS

V.I. Yanko
Nauka Tekh. Gor. Khoz., 1967, No. 9, pages 86–91; Chem. Abstr., 86, 6958 (1968)

Waste water containing mineral and organic compounds, bacteria and biological matter, and acid and alkaline salts can be disinfected by electrolysis. The reactions involved and the physical factors affecting the process are discussed. Disinfection is intensified with depth of submergence of the electrode and degree of mixing of the liquid. Electrolysis gives 99 per cent disinfection.

Keywords: electrolysis and disinfection electrode.

OZONE: THE COMING TREATMENT?

R. McNabney and J. Wynne
Wat. Wastes Engng, 8, No. 8, pages 46–48 (1971)

A flow diagram is given of the pilot plant at the Blue Plains sewage works of Washington, D.C., for studies on ozonation of secondary effluents (see Wat. Pollut. Abstr., 1970, 43, Abstr. No. 1581), and the costs of ozone treatment are estimated and summarized in tables.

Keywords: ozonation, disinfection, secondary effluent and costs

OZONE TREATMENT OF SEWAGE PLANT ODORS

Welsbach Corp., Philadelphis, Pa. Ozone Systems Div.
P.C. Unangst and C.A. Nebel
Water and Sewage Works, Vol. 118, Ref. No., pages R42–R43 (1971)

Ozonation systems have been developed for in-plant odor control applications. Ozone controls odors arising from various sewage plant locations by oxidizing the sulfides and amines produced to sulfoxides and amino oxides, both of which are odorless and non-toxic. The odor producing facility must be covered, having only one exhaust outlet. There must be a minimum of 15 sec. of mixing time between the exhaust gas and the ozone to insure good oxidation and odor removal, assuming that the exhaust fans provide sufficient turbulence and mixing. Proper control of ozonator output can be achieved so that gasses leaving the exhaust stack contain less than 0.01 mg/l of ozone, a safe level for continuous exposure. On-site ozone generation units have been developed which are capable of being fully automated and interlocked with other equipment; maintenance consists of simple cleaning twice annually. Operating costs for units producing from 4 to 200 lb/day of ozone are about 10 kwh/lb ozone produced. Exhaust flow can be easily determined since one lb/day of ozone is adequate to treat 6,000 cfm of exhaust.

Keywords: ozone, odors, oxidation, turbulence, mixing, ventilation, automatic controls, cost analysis, waste water treatment, on-site generation and exhaust.

DISCUSSION OF 'THE INACTIVATION OF ENTEROVIRUSES IN SEWAGE BY CHLORINATION'

Federal Water Pollution Control Administration, Cincinnati, Ohio
N.A. Clarke
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 44—46 (1966)

Virus inactivation was monitored in primary treatment facilities, trickling filters, activated sludge, and chlorine disinfecting units. It was found that little or no virus inactivation occurred in primary treatment, and that the effluents from secondary treatment facilities contained viruses as often as did the raw sewage. The trickling filter reduced the levels somewhat, but still did not provide a nearly virus free effluent. The activated sludge unit provided 90% removal of poliovirus, and 98% removal of coxsackie A9 virus. Bacterial reductions were much less subject to variation in these tests than were viral reductions. Studies indicated that a 9 mg/l concentration residual of chlorine during a 15-minute contact time would be sufficient to inactivate viruses. Raw sewage chlorinated to levels of .1 to .3 mg/l showed no reduction of active viruses over non-chlorinated effluents. From this analysis it was evident that chlorination as it is now being handled is not sufficient to prevent viral growth. Much work is needed to provide methodology with which to analyze viral concentrations in water samples. Also, residual chlorine measurements must be taken along with the samples in order to determine whether a virus is particularly virulent, or whether the chlorine has been reduced to a biologically inactive level. (See also W71-04710.)

Keywords: viruses, chlorination, disinfection, trickling filters, coliform, bacteria, sewage treatment, waste water treatment, enteroviruses, inactivation, polic viruses, echovirus 12, coxsackie A9, fecal streptococcus, plaque counts, hydro-extraction, chlorine residual.

DISCUSSION OF 'THE INACTIVATION OF ENTEROVIRUSES IN SEWAGE BY CHLORINATION'

Vienna University (Austria). Hygiene Inst.
G. Weber—Schutt
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 47—49 (1966)

A municipal sewage treatment plant, having a weak sewage from a combined sewer as influent, and consisting of an emscher tank, trickling filter, and final settling tank, was seeded with staphylocccccus phage 30; 15 minutes after the phage seeding, radioactive sodium was added. Concentration of the phages was monitored at the outlets to the three stages of the treatment plant, as was the level of radioactivity. The flow through curves were then graphed and included in the report. 66% of the phage particles passed through the plant and into the receiving stream. This experiment was then duplicated in a similar plant with similar results. Although not all viruses behave in exactly the same manner as the particular phage used, many do react quite similarly. From these test results it was obvious that plants of this type do not provide adequate inactivation of viruses, and they must be redesigned or replaced.

Keywords: viruses, bacteriophage, radioactivity techniques, epidemiology, pathogenic bacteria, municipal wastes, waste water treatment, staphylocccccus phage 3C, sodium 24, poliomyelitis, clarification and emscher tank.

KINETICS AND EFFLUENT QUALITY IN EXTENDED AERATION

California University, Berkeley, Sanitary Engineering Research Lab
E.J. Middlebrooks, D. Jenkins, R.C. Neal, and J.L. Phillips
Water Research (J Int Assn on Water Pollution Research), Vol. 3, No. 1, pages 39—46 (Jan. 1969)

A plant study is reported of an extended aeration package-type plant (oxigest). During the 4-month period, the substrate removal rate averaged 0.09 lb COD/lb VSS-day (median 0.06). Influent CODs ranged from 160 to 2300 mg/l, and the MLVSS declined steadily from 5110 to 1810 mg/l. Effluent quality remained about 16 ±8 mg/l. Suspended matter in the effluent ranged from 8 to 216 mg/l and averaged 25 mg/l (median 42 mg/l). A significant proportion of the soluble effluent COD and the activated sludge solids was a polysaccharide-like material. Nitrogen data indicated denitrification in the secondary settling tank.

Keywords: activated sludge, denitrification, extended aeration, package plant, comminutor, oxigest, hypochlorinator sludge accumulation, VSS, MLVSS, COD, suspended solids, nitrogen pathways, polysaccharide, substrate removal, and cell yield.

OPERATIONAL STABILITY OF THE EXTENDED AERATION PROCESS

Oklahoma State University, Stillwater, Department of Civil Engineering
A.F. Gaudy, Jr.
Available from the National Technical Information Service, Springfield, Va. 22151, as PB-206 909; $3.00 in paper copy, $0.95 in microfiche; Oklahoma Water Resources Research Institute, Stillwater, Completion Report 1971. 212 pages

This project was initiated to determine if an activated sludge process could operate with total cell recycle over an extended period of time. Previous researchers had concluded that such a process (the extended aeration or total oxidation activated sludge process) could not function and that cell or sludge wastage would be necessary. Some had concluded on the basis of short-term studies that the process was theoretically impossible and that, because of the biological production of an inert organic fraction of cell mass, the sludge concentration would continually build up. The inert fraction would thus become an ever-increasing fraction of the activated sludge and the system would eventually undergo metabolic failure; i.e., lose the ability to purify wastewaters. It was felt that these conclusions had never been subjected to complete testing; also, if the system were to fail, there was need for engineering data to estimate how long such a system could be successfully operated before failure. Accordingly, a laboratory-scale pilot plant activated sludge process was operated in which positive control of sludge retention in the system was obtained by passing all contents through a centrifuge and returning the separated biomass to the aeration chamber. Thus, no sludge was wasted (purposely or inadvertently). This system was operated for 3 years and there was no evidence of metabolic failure; excellent purification was obtained. The sludge concentration did not continually build up, but underwent periods of accumulation and de-accumulation. The periods of de-accumulation corresponded to cycles of metabolism wherein autodigestion of the biomass exceeded new growth due to metabolism of the in-flowing waste. At times the sludge was observed to build up to rather high concentrations, and it was reasoned that the autodigestion might be helped or controlled by an engineering modification of the process in which a portion of the sludge could be withdrawn and subjected to chemical hydrolysis. This concept (the "hydrolytic assist") was tested, and it was found that the hydrolyzed sludge was a readily available substrate for the remaining (unhydrolyzed) sludge. These findings (including a flow diagram for the process) were published. Also, some laboratory pilot plant research has been accomplished which indicates that the new process holds considerable promise.

Keywords: wastewater treatment, aeration, oxidation, sludge treatment, activated sludge, sludge digestion, pilot plants, metabolism, biomass, aerobic treatment, hydrolysis, biological treatment, biodegradation, digestion, total oxidation, extended aeration, aerobic digestion, autodigestion, chemical hydrolysis, and hydrolyzed sludge.

REDOX POTENTIAL—A GUIDE TO OXIDATION POND PERFORMANCE

Auckland University (New Zealand)
O.C. Brockett and P. Welsey
Preprint, presented at 6th International Water Pollution Research Conference, Session 10, Hall A, paper No. 19 (June 21, 1972)

Measurements of oxidation-reduction potential were made in a full-scale oxidation pond at various depths. An area was selected that contained a thick layer of digesting sludge that was also close to a power supply. The three important zones selected for study were the sludge, sludge-liquor interface, and pond top liquor, 10 to 15 cm below the surface. Collection of data was restricted to two seasons: winter when oxidation pond activity is at a minimum, and summer when activity is at a maximum. Allowing for minor variation, the redox potentials of oxidation pond liquor and sludge-liquor interface show a distinctly diurnal pattern. The duration of electropositive values in pond top liquor corresponds to hours of sunshine. Positive peaks in the interface data are of shorter duration with a suggestion of a lag until evening in reaching the maximum in wintertime. The sludge was always electronegative with remarkably constant values. Since pond deterioration must be assumed to be largely associated with weather conditions, redox potentials, while not providing a remedy, may be useful as an early indicator of pond instability.

Keywords: oxidation-reduction potential, oxidation lagoons, monitoring, performance, instrumentation, aerobic conditions, anaerobic conditions, depth, metabolism, sludge digestion, nutrients, and wastewater treatment.

ELECTRODIALYSIS IN ADVANCED WASTE TREATMENT

U.S. Department of the Interior, Federal Water Pollution Control Administration
J.D. Smith and J.L. Eisenmann
Water Pollution Control Research Series Pub. No. WP-20-AWTR-18, 219 pages (Feb. 1967)

A bench-scale experimental study was made to determine the practicality of partially demineralizing municipal wastewater by electrodialysis. Using filtration alone and filtration followed by carbon adsorption as pretreatments, long-term runs were made with a municipal secondary effluent to determine scaling and fouling effects of the water upon the electrodialysis membranes. During these runs a study was made to determine how high a ratio of product rate to concentrate rate could be obtained without forming scale on the membranes. Some fouling of anion membranes occurred with filtration and carbon adsorption pretreatment; without carbon adsorption, fouling was much worse. Scale formation was not a problem at product to concentrate ratios less than 10. At times much higher ratios were obtained without difficulty. The results of these runs indicated that the total operating cost for a 10-mgd electrodialysis treatment plant might be less than 10 cents per 1000 gal.

Keywords: tertiary treatment, electrodialysis, laboratory tests, liquid wastes, water reuse, membrane processes, solvent extractions, scaling, cost analysis, advanced waste treatment, carbon adsorption, secondary effluent, and deionization.

ELECTROLYSIS IN THE FIELD OF EFFLUENT TREATMENT

J.C. Raine
Water Waste Treatment J., 10, pages 633—635 (1966)

A survey is given of electrolytic processes in connection with the following—the production of free chlorine, the Foyn process to precipitate phosphates from sewage, the operation at Cosham, Hants, of a pilot plant employing the Mendia technique for treating sewage, the treatment of gas-works and coke-oven effluents, the plating iron using waste liquor from steel pickling, the oxidation of cyanide solutions, and the treatment of oil refinery waste waters.

Keywords: electrolysis, sewage, trade wastewater, pilot plant, and treatment.

REMOVAL OF SEWAGE NUTRIENTS BY ELECTROLYTIC TREATMENT

Oslo University (Norway), Institute of Marine Biology
E. Foyn
Verhandlungen der Internationalen Vereinigung fur theoretische and angewandte Limologie, Vol. 15, pages 569—579 (Feb. 1964)

The Elkem electrolytic sewage purification process removes from raw sewage the sludge, suspended particles, and bacteria and reduces the content of phosphates to 1.0-1.5 milligram/liter in the effluent. The fraction of removed phosphates depends on the amount of applied electricity, and 200 ampere-hours per cubic meter was found to be most effective.

The purified effluent was active in reducing the biochemical oxygen demand in untreated sewage. The water content of the sludge was reduced 60% by filtration through open sieves.

Keywords: sewage, sludge, sewage effluents, sewage treatment, phosphates, sludge disposal, electrolysis, biochemical oxygen demand, eutrophication, pilot plants, ammonia, nitrogen, hydrogen ion concentration, seawater, turbidity, Elkem electrolytic process, reagent recovery, and magnesium ions.

ELECTROLYTIC SEWAGE TREATMENT AT LE CREUX MAHIE, GUERNSEY

Engineer, London, 222, 231 (1966)

A description is given of the plant for electrolytic treatment of sewage, recently put into operation at Le Creux Mahie, Guernsey. At this plant, which has a capacity of 104,000 gal per day, sewage and cesspool liquor are mixed with electrolysed seawater in the ratio of 1:15; the mixture passes to a disintegrator and is then held in stirred reaction tanks for 1 hour before being discharged into the sea. Electrolysis of the seawater is carried out in a cascade arrangement of two groups of four cells; each cell comprises a plastic tray with the anode, a sheet of platinized titanium, resting on the bottom of the tray and the cathode, a perforated mild-steel plate, being separated from the anode by plastic spacers about 1/4 inch in height. At present St. Peter Port is the only community on the island with main drainage, and the sewage is discharged into the sea without treatment. In other parts of the island, sewage is treated in cesspools and septic tanks, the contents of which are collected by tankers and discharged into the sewers; this can cause trouble since the liquor is often septic and contains sulphates. A comprehensive scheme of main drainage is being prepared for the whole island. In the meantime, much of the cesspool liquor will be treated in the new electrolysis plant.

Keywords: electrolytic, treatment, sewage, and cesspool.

ELECTROLYTIC SEWAGE TREATMENT: THE MODERN PROCESS

H.W. Marson
Water Pollution Control, London (J. Proc. Inst. Sewage Purif.), 66, pages 109—124 (1967)

After outlining the development of electrolytic methods of treating sewage, the author describes the design and operation of the pilot plant at Cosham, Portsmouth, which operates by the Mendia process. The plant treats domestic sewage at rates of up to 12,500 gal per hour, with up to 50% of that volume comprised of seawater. After grit removal and comminution, the sewage is mixed with electrolysed seawater in an accelator sludge separator that has been modified to become two stirred tanks in series. Several types of cell with different electrodes have been provided. Results of the operation are summarized in a table. The liquid portion of the sewage is disinfected within a few minutes, and Esch. coli in the solids is reduced to less than 20 per ml within 30 to 60 minutes. Initially the sludge produced was watery and separation from the treated effluent was incomplete, but further experiments are in progress to improve separation. There is evidence that either the active chlorine or the suspended magnesium hydroxide produced suppresses the formation of detergent foam and also that slick formation is reduced. Studies to confirm these observations are planned. A brief description is also given of the electrolytic treatment plant in operation in Guernsey. In an appendix, A. J. Harrison describes modified techniques developed for the bacteriological examination of crude and chlorinated sewage.

Keywords: electrolysis, seawater, chlorination, disinfection, corrosion, and BOD.

MATHEMATICAL MODEL OF THE ELECTRODIALYSIS PROCESS

Process Research, Inc., Cambridge, Mass.
K.T. Pruyn, J.J. Harrington, and J.D. Smith

Available from GPO Sup. of Doc. as I67.13/4:17090 FTA 7/69, \$0.70; Microfiche from NTIS as PB-200 721, \$0.95; Water Pollution Control Research Series, 70 pages (July 1969)

An electrodialysis unit was established as a control volume, and material balances around the control volume were formulated, involving input and output flows, types of charged particles to be exchanged, concentrations of charged particles, and percentage removal of individual ions, as well as percentage removals of total ions. Significant parameters involved included spacer design geometry, membrane properties (resistivity, current efficiency, separation factors, etc.) and mode of operation of the stack (current density, products stream concentration, waste/product ratio, waste stream pH, etc.). Performance equations were then formulated for resistivity, dc power input, current efficiency, number of stacks required, and the pumping headloss. Cost analyses were then derived to include: 1) electrodialysis stacks, stack piping, distribution piping, and pumps for stack-related costs; 2) rectifiers and process electrical for dc power costs; and 3) acid storage tanks, acid feed pumps, instruments, and miscellaneous equipment for auxiliary costs. Equations derived for capital costs were based on the January 1965 Engineering News-Record cost index. Operational costs were estimated and evaluated in the same manner. The program was run for plants of 1, 10, and 100 mgd, with capital and operating costs being \$164,620 and 7.07 cents/1000 gallons, respectively, for a 1-mgd plant. Program flow charts as well as actual computer outputs are presented.

Keywords: computer simulation, mathematical models, feasibility studies, cost analysis, electrodialysis, separation techniques, membrane processes, semipermeable membranes, anions, cations, demineralization, desalination, resistivity, flow, acid, storage, instrumentation, pipes, pumps, wastewater treatment.

DESIGN AND APPLICATION OF MULTIMEDIA FILTERS

Neptune Microfloc, Inc., Corvallis, Oregon
W.R. Conley and H. Kou-ying
Journal of the American Water Works Association, Vol. 61, No. 2, pages 97—101 (Feb. 1969)

Alternative filter designs using media of different specific gravities and sizes have been built and tested on various kinds of raw water supplies. Some of these data and operating results from various plant designs are presented and discussed. A practical rational method to optimize design, developed for uniform single media filters, can also be used for filters made of three or more nonuniform and different materials. Polyacrylamides drastically change the filter performance for all filters tested and should be considered in filter design. Filter design should not be limited by rule-of-thumb standards and should be specific to individual water sources. Operating results of many plants show that custom design for specific situations is reasonable. Flocculation within filter pores may be important and needs to be reevaluated.

Keywords: water treatment, filters, filtration, design, flocculation, electrolytes, and dual-media filters.

THEORY OF MULTILAYER FILTRATION

University College, Dept. of Civil and Municipal Engineering, London (England)
S.S. Mohanka
Journal Sanitary Engineering Division, American Society of Civil Engineers, Vol. 95, No. SA6, pages 1079—1095 (Dec. 1969)

Mathematical models describing the removal of suspended solids and head loss changes through the depth and during the time of operation of a filter run established in the past gave good correlation with experimental results under particular conditions. Recently a more general equation was used in a multilayer filtration study and was found to predict results matching experimental observations. The relations of the various parameters in the equation with filtering velocity and specific surface have been found for multilayer filtration with flocculent suspensions. The mathematical model was used to predict concentration removal and head loss development in a filter.

Keywords: water treatment, filtration, sanitary engineers, filters, design, head loss, flow rates, flocculation, computers, model studies, mathematical models, backwashing, and multimedia filters.

ULTRASONIC FILTRATION OF COMBINED SEWER OVERFLOWS

American Process Equipment Corporation, U.S. Water Quality Office, Water Pollution Control Res. Ser. 11023DZF 06/70, U.S. Govt Printing Office, Washington, D.C., 56 pages (1970)

Tests on the treatment of simulated storm sewage or primary sewage effluent by an ultrasonically cleaned microfiltration system showed that, when storm sewage was being treated, the porous polyethylene elements became clogged with rust particles from corrosion of the preliminary treatment tanks and piping, but the system was suitable for the treatment of primary sewage effluent. Both crude sewage and storm sewage could be treated with a new flotation vortex separator, and this Vorsep unit could provide preliminary treatment before the ultrasonic microfiltration system.

Keywords: filtration, ultrasonic sewage, and combined sewer overflow.

THE USE OF ULTRAFILTRATION MEMBRANES FOR ACTIVATED SLUDGE SEPARATION

Dorr Oliver, Inc., Stamford, Conn.
C.V. Smith, D. DiGregorio, and R.M. Talcott
Proceedings, Industrial Waste Conference, 24th, pages 1300—1310 (May 6, 7, and 8, 1969)

A sewage treatment facility was developed for a small manufacturing company employing 120 people and creating 3600 gallons of sewage per day. A room 10 feet by 15 feet was allocated for this unit. Dorr Oliver took this opportunity to construct a prototype ultrafiltration unit for liquid-solids separation. Basically the facility is an activated sludge process operated at a high MLVSS (10,000 to 15,000 mg/l), with the ultrafiltration device as a secondary clarifier. The filtration membranes are noncellulosic organic polymers. The filter is constructed so that a thin skin, approximately 5 microns thick, is placed over a porous substructure of the same material. The total thickness of the filter membrane is 6 to 8 mills. The filter operates at pressures ranging from 20 to 50 psi, so the membrane is reinforced with a nonwoven material (paper, in this instance). The filter membranes are assembled in modules of 60 square feet of filtration surface. These modules can then be assembled into any size unit desired. Reactor tank effluent is passed through the filter at 5 fps, and periodically the direction of flow is reversed to prevent solids buildup on the membranes. The ultrafiltration system has been operated for 6 months with 95% BOD removal, 100% suspended solids removal, and a low coliform count in the discharge.

Keywords: wastewater treatment, activated sludge size, filtration, membranes, separation techniques, ultrafiltration, organic polymer, and suspended solids.

FILTRATION

WATER QUALITY MANAGEMENT: Water Treatment and Quality—Turbidimetric Control of Filter Effluent Quality

Iowa State Univ.
J. L. Cleasby
Journal of American Water Works Association, Vol. 52, No. 11, pages 1141—1415
(Nov. 1960)

Turbidity is a very indefinite quality to measure. Many problems prevent an accurate determination of the absolute turbidity level for any water sample. The continuous record of turbidity provided by the new low-range turbidimeter (Hach) is a welcome addition to plant control instrumentation. Turbidity measurement is the best means of continuous control of filter effluent quality. Important uses for the new turbidimeter are: the selection of proper time to backwash filters, the study of feasibility of high filtration rates, and observations of the effect of plant operational practice on effluent waste quality.

Keywords: water treatment, turbidity, control, instrumentation, filtration, water quality, and water supply.

FILTRATION KINETICS IN WATER AND WASTEWATER

California Univ., Berkeley
M. C. Kavanaugh, A. N. Wright, G. Toregas, L. Hallen, and E. A. Pearson
Second Annual Progress Report, 54 pages (August 1971)

Modes of particle deposition in a deep-bed filter are presented, and capacity of the filter to retain particles removed from suspensions is reported for particles of different degrees of stabilization. The transition of filter performance from clogging to breakthrough conditions is found to be controlled by the ratio of particle size to the mean grain size and particle flux. Ranges of applicability of different forms of solids removal (including filtration) are noted. Ionic strength and zeta potential are purported to be influential in terms of filter response. The optimum use of filtration is said to require control of both particle stability and particle size distribution.

Keywords: filtration, model studies, equations, filters, zeta potential, ion transport, pilot plants, optimization, suspension, granules, particle size, and variable analysis.

PRESSURE FILTRATION OF SECONDARY TREATMENT PLANT EFFLUENT

Robert A. Taft Water Research Center, Cincinnati, Ohio; Advanced Waste Treatment Research Lab.
E. L. Berg and C. A. Brunner
Water and Wastes Engineering, Vol. 6, No. 10, pages 54—58 (October 1969)

A field study using a commercial pressure filter to clarify secondary treatment plant effluent is described. Two different filter beds were evaluated: a single-medium filter consisting of 20 inches anthracite coal (effective size 0.75 mm) and a dual-media filter consisting of 6 inches sand (effective size 0.45 mm) and 14 inches anthracite coal. Filtration rates were either 5 or 10 gpm/sq ft and filter performance was determined by measurement of filter headloss, influent suspended solids and effluent turbidity. Four different polyelectrolytes were investigated in conjunction with varied aluminum dosages. Results indicated that cationic polyelectrolytes were more effective in preventing floc breakthrough than were the nonionic or anionic polyelectrolytes. For the single medium filter using dosages of 2.16 mg/l polyelectrolytes and 14.5 mg/l aluminum at a filtration rate of 10 gpm/sq ft. total organic carbon (TOC) removal was 50% and phosphate removal was 17%. Slightly better TOC removal and significantly less phosphorus removal was observed in the dual media filter under similar conditions. Estimates for a 1 mgd capacity plant indicated a total cost of 6.7 cents per 1000 gallons for this type treatment.

Keywords: effluents, pilot plants, filtration, costs, waste water treatment, tertiary treatment, flocculation, operating costs, single medium filtration, dual media filtration, anthracite coal, polyelectrolytes, and aluminum.

POLYMERS IN THE FILTRATION OF RAW SLUDGE

Kansas City Dept. of Water and Pollution Control, Mo.
G. J. Hopkins and R. L. Jackson
Journal Water Pollution Control Federation, Vol. 43, No. 4, pages 689—698 (April 1971)

The solids handling facilities serving Kansas City's two major treatment plants have been in operation since 1966. Kansas City is the first known major U.S. city where the initial design of new sludge treatment facilities provided solely for the use of polymers as the sludge conditioning agent for vacuum filtration of raw sludge followed by filtration of the filter cake. Initially, the system was set up to feed only cationic polymers, but operational difficulties soon dictated the addition of an anionic polymer also. The operating staff, in conjunction with local consulting engineers, has resolved the operational problems that are inherent in early operations of large untested facilities. Chemical suppliers were required to test at plant scale, as well as analytically, their products, and these data combined with competitive bids were used to select the chemicals to be purchased. At the present time, an operating cost of $2.20 per ton of dry solids has been calculated.

Keywords: sludge, dewatering, filtration, sludge treatment, separation techniques, mixing, design criteria, automatic controls, cost analysis, waste water treatment, incineration, polymers, sludge conditioning, and filter cake.

REMOVAL OF ORGANIC SOLUTES FROM WATER BY THE LOW PRESSURE ULTRAFILTRATION PROCESS

Massachusetts Univ., Amherst
D. G. Newton, Jr.
Master's Thesis, University of Massachusetts, 189 pages (February 1970)

Ultrafiltration techniques were investigated in an effort to determine the major factors governing the transmission or rejection of certain solutes by the ultrafiltration membranes. Initially, solutions of one solute in one solvent were used to determine the effect of molecular size on the rejection properties. Data obtained supported the 'pore theory' to the extent that larger molecules were subject to a higher percentage of rejection than smaller molecules. In addition, pure water throughput was also decreased indicative of the molecules caught in the pores acting as plugs and preventing the passage of other molecules. The second phase of the study was designed to determine the effect of having more than one solute in solution. The solution consisted of an organic solute, a surface active agent feed additive, and water solvent. The formation of a liquid surfactant film did not inhibit the passage of the sugar due to its low energy of activation. A history of the development of ultrafiltration was presented along with a design schematic and outline for an efficient, low pressure ultrafiltration apparatus.

Keywords: membrane processes, filtration, organic wastes, solutes, separation techniques, pores, monomolecular films, membranes, pressure, hydrogen ion concentration, permeability, diffusion, osmosis, desalination, surfactants, hydrolysis, design criteria, waste water treatment, ultrafiltration, flux, molecular weight, and rejection.

FILTRATION TECHNIQUES IN TERTIARY TREATMENT

Stanford Univ., Calif.
G. Tchobanoglous
Journal of the Water Pollution Control Federation, Vol. 42, No. 4, pages 604—623 (April 1970)

A thorough investigation of filtration techniques used for treating settled secondary effluent is described. The removal efficiency for filtration without the addition of chemicals is primarily a function of grain size. Typical removal efficiencies using conventional single medium sand or anthracite filter beds with depths of 18 to 30 inches varied depending upon the grain size from 10 to 60%. In the filtration of settled effluent with and without the addition of chemicals turbidity breakthroughs were not observed within the headloss range studied, 8 to 10 feet. As presently designed the sand layer in most duel medium filter beds is not utilized effectively. In multi-media filter bed if the anthracite layer is greater than 16 to 20 inches media placed below the anthracite contributes little to the overall suspended solids removal. Polyelectrolytes can be used as an additive to achieve varying degrees of suspended solids removal from secondary effluents using single, dual and multi-media filter beds. The distribution of suspended solids removed within a filter bed can be controlled by varying amount and point of addition of polyelectrolytes.

Keywords: filtration, tertiary treatment, performance, headloss, sewage treatment, waste water treatment, activated sludge, pilot plant, turbidity, mathematical model, design, operations research, removal mechanisms, polyelectrolytes, and suspended solids.

TERTIARY FLOCCULATION AND FILTRATION

Dayton, Ohio
D. Tossey, P. J. Fleming and R. F. Scott
Journal of the Sanitary Engineering Division, Proceedings of ASCE, Vol. 96, No. SA1, pages 75—90 (Feb. 1970)

The conventional water treatment processes of flocculation, sedimentation, and filtration were studied in a 0.5 mgd pilot plant to demonstrate their applicability in tertiary treatment of trickling filter effluent. It was demonstrated that significant effluent quality improvements can be made employing these processes. Lime and alum were used as primary coagulant aids. Optimized treatment schemes and chemical dosages produced effluents containing 4 mg/l BOD5, 25 mg/l suspended solids, and 5 mg/l phosphate. Capital and operating cost estimates for a full-scale plant treating 75 mgd of trickling filter effluent ranged from 37 cents/1000 gallons to 43 cents/1000 gallons depending upon the chemicals employed.

Keywords: flocculation, tertiary treatment, filtration, efficiencies, biochemical oxygen demand, nutrients, phosphate, sedimentation, costs, and waste water treatment.

SOLIDS SEPARATION BY ULTRAFILTRATION FOR CONCENTRATED ACTIVATED SLUDGE

Syracuse University, N.Y. Bioenvironmental Engineering Div.
F. W. Hardt, L. S. Clesceri, N. L. Nemerow and D. R. Washington
Journal Water Pollution Control Federation, Vol. 42, No. 12, pages 2135–2148 (Dec. 1970)

An investigation of the feasibility of separating the suspended material from the mixed liquor and recycling this material back to the biological reactor as a means of treating high-BOD wastes was conducted. This involved passing feedwater at an elevated pressure across synthetic membranes where the larger dissolved solids and suspended material are retained by the membrane and recycled back through the activated sludge plant. Analytical methods included daily monitoring of the COD, total and orthophosphates, TOC, MLVSS, SS, inorganic solids, respiration rate, and the molecular size of the dissolved solids in the mixed liquor and the ultrafiltrate. This process showed a 98% COD reduction but had a gradual accumulation of detained DS of molecular weights greater than 1000 which essentially removes all bacterial solids from the effluent stream.

Keywords: filtration, activated sludge, biochemical oxygen demand, microorganisms, membranes, filters, pressure, hydrogen ion concentration, chemical oxygen demand, phosphorus, respiration, gels, solvents, solutes, waste water treatment, mixed liquor, volatile suspended solids, ultrafiltration, ultrafiltrate flux, total organic carbon, and cell lysis.

THE IMPORTANCE OF ZETA POTENTIAL TO THE WATER INDUSTRY

Universidad Nacional Autonoma de Mexico, Mexico City, Instituto de Geofisica
R. A. Deju
Water and Sewage Works, Vol. 116, No. 12, pages 460–464 (Dec. 1969)

The theoretical considerations and applications of zeta potential to the water and waste water industry are discussed. Zeta potential is defined as the charge of a particle at the periphery of its stern layer and for aqueous solutions it is determined by measurement of electrophoretic mobility. Instruments available for measurement of the long-ross, mass-transport cell with associated power supplies and microelectrophoresis apparatus suited to dilute solutions which can be employed rapidly, requires only small amounts of solution and requires no microscopic examinations is described in detail. Although the conducting unit and power supply are similar to earlier microelectrophoresis instruments, this version employs a projection and lens-filter system permitting the projections of images of the particles on a screen for rapid easy electrophoretic mobility determinations. General applications of zeta potential to the water and waste water industries are discussed including: colloid precipitation and/or dispersion, control of flocculating agent dosage, alkylbenzene sulfate or detergency control in water and waste water treatment operations and identification of the nature of the surface of living bacteria. There are other uses of zeta potential in the water industry and its uses in waste water treatment and disposal are considered enormous.

Keywords: zeta potential, waste treatment, waste water treatment, instrumentation, electrophoresis, colloids, industrial wastes, electrophoretic mobility, moving-boundary cell, mass-transport cell, and microelectrophoresis.

CHICAGO'S CENTRAL WATER FILTRATION PLANT

Department of Water and Sewers, Chicago, Ill.; and Department of Public Works, Chicago, Ill. (1966)

The operation of Chicago's central water filtration plant is described. The plant is the world's leader in output. It produces filtered water at a rate of 960 million gallons a day. Located on a 61 acre peninsula on Lake Michigan the plant normally receives raw water through tunnels from intake cribs located in Lake Michigan. A shore intake is also available. The filtration process starts at the north end of the plant where the water is brought in. After passing through 8 screens, the water is pumped to an elevation of 21 feet and flows by gravity through the rest of the processes. Chemicals are added, using the most advanced feeding systems, as the water flows to the mixing basins, then on to the settling basins where 85 to 90 percent of the impurities are removed by sedimentation, enhanced by alum-floc coagulation. The water is then passed on to the filtration building where the final polishing operation is completed before flowing into clearwells and thence to the filtered water reservoir awaiting distribution. The processes, from start to finish, are monitored, centrally displayed and recorded, supervised, and manually controlled using a centralized complex of special instruments and a computer-data-logger. A closed-system television system is used for making visual checks of strategic points. Information gathered is used to increase efficiency of plant operations.

Keywords: water treatment, water purification, filtration, filters, water supply, water works, treatment facilities, construction, operations, monitoring, data collections, instrumentation, and Chicago Water Department.

THE USE OF MICROSTRAINERS AND SAND FILTERS FOR TERTIARY TREATMENT

P. C. G. Isaac and R. L. Hibberd
Water Research, Vol. 6, page 465 (1972)

Tertiary treatment is increasingly applied to normal secondary effluents to remove solids and to reduce BOD. The two processes most frequently used in Britain for large works are microstrainers and rapid sand filters. This paper reviews these processes and discusses their effectiveness and cost. The cost data are partly culled from the papers quoted in this

review and partly from questionnaires that were sent to the managers of all those sewage works where tertiary treatment was in operation. Annual operating costs for microstraining units are of the order of 2% of capital cost. A large decrease in cost with increase in scale cannot be expected with this kind of treatment, which is increased in capacity by replication of smaller units. In spite of the high cost of rapid gravity sand filters, it is probable that rapid sand filtration is the only tertiary treatment that can be relied upon to achieve high standards consistently.

Keywords: microstrainers, sand filters, costs, and tertiary treatment.

MODEL OF OPTIMAL COMBINATION OF TREATMENT AND DILUTION

Oklahoma Univ., Norman. Dept. of Civil Engineering and Sanitary Science
W. Reid, Leale E. Streebin, Robert Y. Nelson, and O. Tom Love

Proc 3rd Annu Amer Water Resources Conf (Nov 8-10, 1967) San Francisco, pages 339—350 (1967)

Models were developed to depict waste dilution flows used with projections of reservoir and treatment costs to provide optimal combinations of low flow augmentation and waste treatment. Projection of municipal and industrial loadings were developed on a nationwide data base using standard statistical methods. The study revealed mean and variances of strength and discharges. A similar study developed treatment efficiency matrices and corresponding treatment costs. These costs reflected scale effects, and were presented in terms of capital, operation, and maintenance costs. A novel technique employing micro and macro models and 'tunneling' procedure was used to disaggregate national values and to provide basin loading level forecasts. Stream input-output models were developed in terms of responses to impressed loads, characterized as biodegradable, nutritional, persistent chemical, and thermal. The models were developed as a function of stream parameters. The loads and stream resources were treated on a basin level in these macro level models. The model provides optimal or least cost combination of waste treatment and dilution.

Keywords: waste treatment, waste dilution, water quality control, optimization, mathematical models, systems analysis, computer programs, model studies, costs, economics, streamflow, water temperature, biochemical oxygen demand, waste treatment-dilution optimization.

DYNAMIC PROGRAMMING FOR A SEWAGE TREATMENT SYSTEM

Yachiyo Engineering Co., Tokyo (Japan)
T. Futagami

Fifth International Water Pollution Research Conference, San Francisco (July 26–August 1, 1970)

An optimal sewage system is studied by using dynamic programming. This dynamic programming is based on the principle of optimality and has the advantage of being able to handle the complicated planning problems. A mathematical model of river system is constructed for the application of dynamic programming. The concentration of the polluted material in the river and the treatment rate at each municipal waste water treatment plant are chosen as the state variable and the decision variable respectively. The objective function considered includes the construction cost and treatment cost at each waste water treatment plant and chemicals costs for water supply. Taking account of the purification of river, the functional equations are derived for the application of dynamic programming. The recurrence formulae are derived to obtain the optimal planning. Finally, dynamic programming is applied to the Yodo River System by using the derived recurrence formulae and grid method. In this research the backward calculation procedure of dynamic programming is adopted.

Keywords: Sewage treatment, dynamic programming, systems analysis, mathematical models, standards, optimization, water quality, waste water treatment, flow chart and grid method.

BIOLOGICAL SYSTEMS AS POLLUTION MONITORS

Virginia Polytechnic Inst., Blacksburg. Dept. of Biology
Cairns, Jr., R. E. Sparks, and W. T. Waller
Research/Development, Vol. 21, No. 9, pages 22–24 (Sept 1970)

The use of continuous monitoring of the activity of aquatic life in a stream to detect an increase in the level of pollutants before the increase reaches the danger levels was studied using fish in tanks. Three biological parameters of fish—movement, breathing and electrocardial activity—are monitored with two types of apparatus. Basically, each apparatus consists of test chambers in which are maintained fish, sensing devices, amplifiers and records. The swimming movement monitor uses photoresistors as sensors. One fish is maintained in each of six 5-gallon aquaria. Each aquarium is traversed by light beams at the top, middle and bottom levels. When a fish moves through a light beam at a particular level, a photoresistor acts through an amplifier to make a blip on an event recorder and to advance a digital counter. The breathing and electrocardial monitor uses a needle electrode inserted in the breast of the fish as a sensor. By using biological monitoring systems, it is possible to obtain quick information as to when a waste toxicant level changes. The type of information generated is of such a nature that it can be fed directly into a computer, and the time lag in determining changes can be significantly reduced.

Keywords: monitoring, water pollution control, water pollution effects, bioindicators, fish, water chemistry, toxicity, trace elements, poisons, waste disposal and water pollution monitoring.

PHILADELPHIA'S PLANS TOWARD INSTRUMENTATION AND AUTOMATION OF THE WASTE WATER TREATMENT PROCESSES

Philadelphia Water Dept., Pa.
C. F. Guarino and G. W. Carpenter
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

For the past several years, the City of Philadelphia has been working towards the instrumentation and automation of the Northeast Water Pollution Control Plant. The plant is designed to treat 175 MGD with a combined average suspended solids and biochemical oxygen demand removal of approximately 75%. The data logging program named 'Nelog', which has been in use since January 1967, reduces the time required for record keeping, minimizes human errors, and enables analysis of data which would be impractical if attempted manually. The computer generates a monthly operational report as well as a monthly summary and an annual report. The Nelog program evaluates the data and produces an output listing any deviation from that which is considered normal or acceptable. This report is brief and enables the technical personnel to review and/or reject questionable data. The Philadelphia Water Department conceived a master plan for the automation of the Northeast Water Pollution Control Plant entitled 'NE-PAT', Northeast Plant Automated Treatment. The initial phase includes all the necessary steps leading to a digital computer system installed on line at a secondary waste water treatment plant. Data that will be collected by the system shall include dissolved oxygen, total suspended solids, turbidity, BOD, TOC, COD, sludge volume index, nutrients (N and P both Total and Ortho) CO2, CH4, total dissolved solids (effluent) and settleability of sludges.

Keywords: waste water treatment, sewage treatment, instrumentation, automation, programs, mathematical model, computers, information retrieval, data processing, Philadelphia, Pennsylvania and flow diagram.

A SPORADIC MONITORING AND CONTROL SYSTEM

D.I. Ageikin, Yu T. Knopov and N.N. Kuznetsov
Pribory i Sistemy Upravleniya, No. 4, pages 32—35 (April 1970)

Experience has shown that even at the highest level of automation, the human operator is still the main link in the control system. However, with the growing complexity of control systems for technological processes, the increased number of controlled parameters, and the limited ability of a human operator to process information, more sophisticated control systems are needed. Sporadic control systems are proposed for continuously operating processes whose parameters have particular zones of permissible values and where emergency situations arise when one or more parameters lie outside these zones. In a sporadic control system, the operator receives signals that parameters have exceeded set limits, just as in other systems. By inserting particular perturbations into the system, the operator can simultaneously displace the settings of all, or a group of, the controlled parameters. By altering the perturbations through calibrated knobs, the operator obtains information about the state of the entire group of parameters, which is sufficient for decision making or forecasting. Several advantages and several possible forms of such a system are discussed, and several possible forms of the system are diagrammed and described.

AUTOMATING TREATMENT MONITORING AND CONTROL

Calgon Corp., Pittsburgh, Pa.
H. M. Rivers and G. W. Schweitzer
Journal of American Water Works Association, Vol. 63, No. 8, pages 533—540 (August 1971)

Examples are presented to highlight certain important factors in water treatment automation technology. (1) Effective use of automation chemical analyzers that are, themselves, miniature water-treatment processes that must be correctly automated in their own right. (2) Achievement of long-term reliability dependent upon only a minimum amount of routine maintenance. (3) Recognition of, and safeguard against, dangerous errors or interference in critical automatic analyses. (4) Reliance upon well-established control concepts; avoidance of all equipment not thoroughly proved to be necessary and trustworthy. (5) Integration of process sensors and process controllers into a logical automation entity. (6) Understanding and complying with the fundamental chemistry of the treatment processes involved. Treatment applications incorporating these factors have been successfully automated in actual practice. Each time a treatment process was effectively automated for the first time, a new automatic chemical analyzer was brought into being, new chemical control concepts were evolved, and water-treatment technology as a whole achieved some new measure of maturity.

Keywords: water treatment, automation, reliability, maintenance, chemical analysis, monitoring and automatic control.

AUTOMATION IN PLANT MODERNIZATION

G.S. Clapham
J. Wat. Waste Treatment, 11, pages 32—33

An illustrated description, with flow diagram, is given of the modified plant at the sewage works of Mitchell Laithes, Yorks., which now serves also Batley, Mirfield, and part of Ossett, treating a total dry-weather flow of about 73 m.g.d., 70 per cent of the load being due to trade waste waters containing toxic metals. After screening and grit removal, the flow from the first three areas passes to primary sedimentation tanks which also receive the flow from Ossett from balancing tanks after separate screening and grit removal. Secondary treatment is by biological filtration and the final effluent is discharged to the river Calder. Provision is made for regulated recirculation of the secondary effluent by 4 automatically controlled pumps and also for a system of partial double filtration, the flows in each system being co-ordinated in a distribution chamber; a change from one system to the other is effected automatically according to prescribed ranges of flow rates. Humus sludge is returned for primary treatment and primary sludge is discharged to lagoons followed by disposal for agricultural purposes.

Keywords: automation, primary treatment, pumps and biological filtration.

AUTOMATIC EQUIPMENT FOR MEASUREMENTS AND ADJUSTMENTS IN THE CONTROL OF WATERS AND SEWAGE TREATMENT

E. Knop
Reprint from VDI Z, 107, pages 1429—1434 (1965)

An illustrated description including experimental results is given of methods and apparatus used for the analysis of sewage in activated-sludge tanks, of effluent air, and of receiving waters, and the application of these measurements in relation to the design and operation of treatment plants is discussed. An automatic instrument panel, connected to an illuminated flow diagram, is designed to adjust and control the concentration of waste waters, setteable solids, BOD, permanganate demand and maximal permissible concentration to fish; a warning light indicates when a danger point is reached. In larger treatment plants the automatic measuring device becomes more complicated and plans are under preparation for the use of a computer to calculate the required data, to assess hypothetical situations, and to solve existing and potential problems and make difficult estimations. Measured values are typed onto magnetic tape, which is fed into the computer and can then be transmitted by radio or telegraph to any required distance. The author stresses the need for an international coding system, using standard measuring units for automatic measurements in water and sewage treatment.

Keywords: control, activated sludge instruments, computers and telemetry.

MEASUREMENTS AND REGULATIONS IN THE OPERATION OF SEWAGE WORKS

R. Kayser
Ost. Wasserw., 21, pages 280—287 (1969)

Details are given of recent developments in methods and equipment for programmed automatic control of the most important sewage-treatment processes, and of factors which have to be known before a programme can be planned and run. The automatic control of the oxygen balance in aerations systems, the control of gas production in digestion tanks, and especially the continuous control and adjustment of the flow of sewage, using the automatic control system closed loop, are outlined. This system, in the event of changes in the controlled conditions can effect adjustment by creating a feed-back; in addition, the control system can issue a local instruction to the final control element "the regulating unit" which then enters into the control process. To control the oxygen supply in large sewage works pole-changing motors are employed, which have speed regulators. An equation is given for the calculation of the maximal oxygen consumption under automatic operating conditions. Results obtained by automatic control for operational efficiency, e.g. of oxygen balance, flow of sewage, sludge load and dry solid contents in sludge, were in good agreement with those determined graphically.

Keywords: closed loop control, oxygen balances and equations.

FEASIBILITY OF THE METROPOLITAN WATER INTELLIGENCE SYSTEM (INTEGRATED AUTOMATIC OPERATIONAL CONTROL)

American Society of Civil Engineers, New York
M. B. McPherson
Available from the National Technical Information Service as PB-207 301, $3.00 in paper copy, $0.95 in microfiche. ASCE Urban Water Resources Research Program Technical Memorandum No. 15, 110 (December 1971)

Feasibility of multiservice, or integrated, water resource automatic operational control on a metropolitan scale encounters several obstacles. Because no example of a metropolitan agency with total areawide, integrated water management authority exists, there is presently no identifiable potential user. Who would pay for the control system is a related enigma. Some necessary sensors for automation are absent, particularly for water quality control and wastewater treatment. However, the much larger technical problem is in the development of required 'software', including control logic and mastery and simulation of certain processes. Development progress is insufficient to assess the probable effectiveness of the concept in meeting basic performance criteria: service, reduced total costs, conflict amelioration, reliability, offsetting increased system complexity, and reducing system vulnerability to disruption. However, the present trend is an accretion of capability, and several levels will probably develop simultaneously in response to varying local requirements and conditions. Automation of water distribution systems has advanced the farthest and total control may soon be achieved. Documented cases supplemented by personal discussions are included, illustrated mainly by examples of the most advanced technology.

Keywords: automatic control, operations, automation, water management (applied), control systems, integrated control measures, areal, remote control, monitoring, mathematical m models, computer programs, telemetry, instrumentation.

DIGITAL COMPUTER SIMULATION OF WASTE WATER TREATMENT

Massachusetts Univ., Amherst
P. W. Cummings, Jr.
Master's Thesis, University of Massachusetts, 171 pages (August 1969)

The basic activated sludge waste water treatment was simulated under the direction of Robert Smith at the Cincinnati Water Research Laboratory. This computer simulation was then used as the basis for further modification and refinement. Following conception, construction, and testing of the modifications, new subroutines incorporating the modifications were integrated into the original program. Developments modeled in this manned included: (1) the exclusion of primary settling, (2) aerobic sludge digestion, and (3) a more thorough analysis of sand bed sludge dewatering techniques. Cost analyses indicated that omission of primary sedimentation would result in overall savings of from 7.53% to 11.01% as compared to conventional activated sludge with primary treatment. Sand bed sludge drying was compared with vacuum filtration and incineration and at 2.4 cents/1000 gallons, was found to be considerably more economical. Anaerobic and aerobic sludge digestion were of nearly the same cost, but if sand bed sludge drying was to be used, a substantial final savings would be realized from aerobic digestion due to the better dewatering characteristics of aerobically digested sludges.

Keywords: digital computers, computer simulation, activated sludge, cost comparisons, evaluation, anaerobic digestion, aerobic conditions, sedimentation, sludge, dewatering, biochemical oxygen demand, temperature, organic loading, odor, hydrogen ion concentration, alkalinity, aeration, oxidation, waste water treatment, subroutines, modifications, volatile solids, and detention time.

MUNICIPAL WASTE-WATER TREATMENT PLANT INSTRUMENTATION

R. H. Babcock
Wat. Wastes Engng, 5, No. 8, pages 46—51 (1968)

The application of instrumentation to the activated-sludge process, biological filtration, and anaerobic digestion, in the treatment of sewage, is described, together with remarks on devices for flow measurement of sludge gas and control of chlorinators. Schematic diagrams illustrate positions of the instruments in the systems.

Keywords: instrumentation, sensors, sewage treatment, gas and biological.

VALUE OF INSTRUMENTATION IN WASTE WATER TREATMENT

Albright and Friel, Inc., Philadelphia, Pa.
J. Salvatorelli
Journal of the Water Pollution Control Federation, Vol. 40, No. 1, pages 101—111 (Jan. 1968)

Instrumentation is described as a valuable tool which, if used properly by the operator, will free him to perform duties which require human attention. Mechanical, physical, and chemical methods may be used to control various processes within a system. Instrumentation for specific values are described, e.g., flow measurements, liquid levels, in wet wells, operating pressure records, continuous recording, pH, temperature, and density analyzers. Specific applications are given for industrial waste treatment as well as domestic waste water. The example for the industrial waste treatment is that of a metal waste which contains heavy concentrations of cyanide, chromium and other heavy metals. Each treatment phase depends on maintaining optimum pH to ensure use of the minimum amount of chemicals needed to carry out the reaction. The burdensome job of maintaining optimum pH at the beginning of each of the treatment cycles was accomplished entirely by pH instrumentation and direct control of chemical application. The second illustration of a system is designed primarily for monitoring an entire waste water disposal system including pumping stations, overflow diversion chambers, and the treatment plant. Because of the magnitude of the system, instrumentation and control at the waste water treatment plant has been limited to only those functions which were necessary for proper plant operation. Costs are usually less than 5% of the total projects costs.

Keywords: instrumentation, control system, waste water treatment, flow, industrial wastes, sewage treatment, monitoring, operation and maintenance, sewers, centralized control and meters.

SENSORS FOR THE ANALYSIS AND CONTROL OF BIOLOGICAL PROCESSES

Metropolitan Sanitary District of Greater Chicago, Ill. Research and Development Lab.
D. R. Zenz, T. J. McAloon and C. L. Weddle
Proc Amer Chem Soc Symp on Water, Air, and Waste Chem (April 13—18, 1969),
Minneapolis, Minn. (1969)

Available and experimental instruments for monitoring activated sludge and anaerobic sewage treatment processes are surveyed. The main difficulty encountered with most instruments is fouling of the sensor process lines and other equipment in a contact with the samples. This fouling is primarily caused by grease and solid accumulations which result in excessive maintenance and recalibration. These problems in many instances can be minimized by homogenization of the sample stream before analysis and making provisions for automatic flushing of the instrument. Instruments to measure pH, temperature, dissolved oxygen and sludge level have been satisfactorily applied on a continuous basis. The Chicago Metropolitan Sanitary District is presently employing temperature, dissolved oxygen and sludge level detection instruments to automatically control some aspects of biological treatment. In addition, treatment plants can be operated with the aid of advanced computer techniques in conjunction with improved mathematical models that accurately describe the behavior of these processes. This type of advanced system could also have instant readout of the operating and analytical parameters and memory bank capable of storing historical data for process investigation.

Keywords: sewage treatment, monitoring, sampling, measurement, instrumentation, research and development, mathematical models, control systems, activated sludge, anaerobic digestion, biological treatment and sewage treatment monitoring.

ADVANCED WASTEWATER CONTROL SYSTEM

Yeomans Brothers Co., Melrose, Ill.
E. F. Bradley
J. Water Pollut Cont Federation, Vol. 41, No. 7, pages 1292—1298 (July 1969)

Because, from a public health standpoint, the effluent from a normally operated domestic wastewater treatment plant has adverse effects on the receiving water, a new treatment process has been developed which provides for effective pathogen removal and absolute continuous control over the quality of the treatment plant effluent. This treatment is accomplished by controlled flow, continuous automatic equipment monitoring, continuous automatic evaluation of the degree of treatment provided, detection of equipment malfunction, instantaneous notification of authorities, and automatic stoppage of flow to the receiving waters. A research project at St. Michaels, Maryland, is expected to provide sufficient test data to verify the validity of the system under full-scale conditions, and also should demonstrate the usefulness of ultraviolet light as a means of disinfection comparable to present chlorination methods.

Keywords: wastewater, lagoons, monitoring, wastewater treatment, disinfection, instrumentation, ultraviolet radiation, research project, St. Michaels, Maryland, effluent shutoff, continuous monitoring and automatic monitoring.

CONTROL SYSTEMS FOR WASTEWATER TREATMENT PLANTS

J. F. Andrews
Water Research Vol. 6, pages 575—582 (1972)

Wastewater treatment plants require skilled operation because of large influent variations, but most plants are in a primitive state with respect to process operation. Modern control systems improve operations which leads to lower pollution loads on receiving streams and increased productivity per unit of plant capacity. Manual control and indicating recording instruments rely on operator generated control, usually on an intermittent basis; local automatic and centralize automatic controllers continuously generate corrective actions based on measurements and controller logic. Process control computers range from data loggers up to optimal controllers, but only the two extremes are discussed. Changeable control strategy, and process interaction accountability are the major advantages of computer control; potential disadvantages include high costs and high level training for operators. Typical functions for data loggers include: scanning process and equipment sensors, data processing; statistical analysis; detect high-low limits; prepare operating logs; furnish operating guide. Although optimal control has rarely been achieved, it is a goal for most computer controlled plants. With this type of control, the computer takes over operation of the plant. Not withstanding the advantages of feed forward control, lack of knowledge on the dynamic behavior necessitates feedback control in most wastewater treatment plants; some treatment facilities employ combination feed forward feedback. Other investigators reported that improved operations through automatic control are economically justified. Compared to the 12% of plant cost for instruments and control devices in the chemical and petroleum industry, the 1 to 1.5 percent spent on control systems in wastewater treatment plants indicates that the treatment plant could profit from additional investments in automatic control. Lack of reliable sensors has inhibited the effectiveness of automatic control in wastewater treatment plants.

Keywords: instruments, automatic control, wastewater treatment, computers, feedback, feed forward and economics.

CONTROL AND AUTOMATION IN WATER-WORKS

Polish Association of Sanitary Engineering and Technology, Warsaw
H. Janczewski
Gaz Woda Tech Sanit. 44(12): pages 390—393 (1970)

Methods of planning control and automation in water-works are given. Most water-works now control such indices as pressure, flow and water level. Actual possibilities for control however, are must greater. Special attention should be given to water pressure, a problem already solved in many countries. Remote control of various equipment cannot be recognized as automation, nor can information disseminations by means of tele-equipment. On the basis of present experience such mechanical and chemical processes as rinsing filters, determining FE and MN content, as well as content of certain other components can be made automatic. Broader application of automation will be possible only after water treatment and distribution are automatic.

Keywords: automation, control and water-works.

COMPUTER CONTROL—ARAKOWA TREATMENT PLANT

S. Tohyama
Water Research Vol. 6, pages 591—595 (1972)

Advantages of computer control systems include: manpower saving; decreased operating cost; high grade quality control; improved management; and treatment optimization. The contemplated computer control system will supervise wastewater treatment, sludge treatment, power equipment and electric equipment. This system consists of the following equipment: central supervisory control board; instruments and its panel board; computer control system; telemeter, telecontrol; relay control; ITV equipment; broadcasing equipment, local operating board. For increased reliability, analog controllers and manual operation, central or local back up the computer system. Because automation is especially effective at sludge treatment works and relay pump stations, the author expects decreased operating costs.

Keywords: computer control, wastewater treatment, supervision, reliability and sludge treatment.

SEWER CONTROL AND PLANT AUTOMATION

J. J. Anderson
Water Research 6, pages 611—615 (1972)

Several combined collection sewer systems—Minneapolis St. Paul, Detroit, and Cleveland—are computer controlled during storm events; scheduling loads by either in-line or external storage should also improve dry weather operations. Utilizing the Minneapolis St. Paul sewer as an example, the author shows that the maximum to minimum flow is about 1.8 to 1 and the COD flux ratio is approximately 3 at the treatment plant with no regulation. Storage volume equal to 8 percent of the daily flow provides hourly flow equalization and reduces the COD flux with flow ratio of 1.6. Since commonly employed unit processes are flow and flux sensitive, a compromise between flow and load equalization should be best. Although not conclusive, preliminary fourier transform analysis indicated that flow equalization should reduce the COD discharge considerably but some process instability may result. Since the Minneapolis St. Paul sewer has 10 to 20 percent dwf storage capacity, external storage is not required. Partially or fully equalized flow or mass flux will improve standard operation and lessen the load change requirements of automatic control devices.

Keywords: storm water control, in-line storage, dry weather and operations, load equalization, flow rate equalization, transform and computer control functions.

AUTOMATIC CONTROL SYSTEM

R. Wood
Water Research 6, pages 583—585 (1972)

Each type of control—manual, remote, automatic operation, and automatic plant—has its place in a modern treatment facility. Selection criteria includes: man power, both operational and maintenance; effectiveness; reliability and cost in terms of both capital and operating. The author comments on the physical control of a 15 MGD activated sludge plant in South-East England.

Keywords: automation, selection criteria, operation and maintenance and cost benefit.

ADVANCED WASTE TREATMENT IS HERE TO STAY: D.C. GETS AUTOMATED

Anonymous
Water and Wastes Engineering, New York, 9 (11), pages 38—39 (Nov. 1972)

The District of Columbia is upgrading its Blue Plains water pollution control plant to produce an effluent with BOD concentration of 4.5 mg/1, P of 0.21 mg/1, and N of 2.4 mg/1. The system, now under construction, consists of primary settling and a three-sludge biological treatment sequence for BOD and N removal. A description is given of the various treatments and their order of use. A complete data-logging system to monitor plant operation is being designed, and an increase of $0.28/1,000 gallons of wastewater processed is projected.

Keywords: wastewater treatment plants, activated sludge process, settling basins, data systems, District of Columbia and AWT.

ATLANTA SPENDS $45—TO INNOVATE AND AUTOMATE

Anonymous
Water and Wastes Engineering, New York, 9 (9), pages 48—51 (Sept. 1972)

The modernization and expansion of the R. M. Clayton Water Pollution Control Plant in Atlanta are described. An extensive control system is being installed that will measure sewage, sludge, water, air, and gas flows. The quality parameters (including oxidation-reduction potential (ORP), pH, DO, C1 residual, suspended solids, and temperature will be continuously monitored. Control panels with graphic displays (including annuciators) will be installed in each major unit for local control; master control will also be provided. A direct digital control computer will assume large portions of automatic control of processes and will serve as a data logger. Of approximately 190 mgd of secondary sewerage treatment capacity on the Chattahoochee River for the Atlanta metropolitan area, this plant will account for about 63% of the total treatment capacity. Also presented are contracts let for construction of the plant, major equipment, and unit design data and loadings. The actual treatment process is described, including the use of special equipment such as dual-fuel engines that can burn sludge gas, natural gas, or fuel. Costs for construction will probably exceed $45 million, and operating costs will probably be about $2 million/year.

Keywords: municipal wastewaters, wastewater treatment plants, computers, monitoring systems, Georgia and Atlanta.

WASTEWATER TREATMENT PLANT CONTROL

EPA, Office of Research and Monitoring, Advanced Waste Treatment Research Laboratory,
Cincinnati, Ohio
R. Smith

Available from National Technical Information Service, Paperback 213-827. Presented at Joint Automatic Control Conference, Washington University, St. Louis, Mo. (August 11—13, 1971)

Because of the difficulty of assigning a cost penalty to environmental damage caused by poor quality effluent being discharged from a wastewater treatment facility, the author assumes that some level of effluent quality is required and examines the economic impact of instrumentation and automation. After delineating the goals of instrumentation and automation that revolve around increased reliability at decreased cost, several principal control loops for a conventional treatment plant are identified. Based on good operating procedures, a rationale is developed for selecting process control schemes. In tertiary or independent physical chemical treatment, chemical feeding and pH control loops are essential for effective treatment. As examples, phosphorus removal (via mineral addition to the aerator and lime precipitation) and nitrogen removal (via nitrification-denitrification and breakpoint chlorination) are discussed. Since the equipment, structure, manpower, chemical utility, and instrumentation costs are functions of the degree of treatment, the designer and plant manager should use the correct mix to effect satisfactory treatment at minimum cost. From the slope of degree-of-treatment cost charts for BOD_5, SS, COD, phosphorus, and nitrogen, the incremental cost for increased removal can be calculated. In general, the incremental removal cost increases as the residual concentration decreases; the cost for treatment for a specified degree decreases as the plant size increases. With this data the cost factors can be compared to each other, assuming that effluent quality is fixed; thus, certain kinds of instrumentation and automation can be economically justified. To demonstrate the rationale for relating manpower, equipment, structure, and automatic control equipment. the author considers examples of primary sludge pumping control via nuclear density to regulate digester loading, sludge blanket control, DO control, reduced overflow rates for final clarifiers, and oversized sludge return pumps for a 10-mgd activated sludge plant. Based on 1971 cost data for nonsupervisory workers in sanitary systems and a 10-year life expectancy for instruments and control equipment, one manyear is equivalent to \$64K invested in instrumentation and control equipment. From recently published studies, water treatment plants spend 5% of construction costs for instruments and automatic control; wastewater treatment plants spend only 1% of construction costs for instruments and automatic control equipment.

Keywords: wastewater treatment, automation, instruments, process control, economics, manpower, structure sizes, utility costs, and chemical costs.

AUTOMATION AND CONTROL OF PHYSICAL—CHEMICAL TREATMENT FOR MUNICIPAL WASTEWATER

EPA, NERC, Advanced Waste Treatment Research Lab., Cincinnati, Ohio
J.J. Convery, J.F. Roesler, and R.H. Wise

Proceedings of International Conference on Water Pollution Research and American Institute of Chemical Engineers, Vanderbilt University (Sept. 18—22, 1972)

The Blue Plains pilot plant in Washington, D.C., is being used to evaluate the economic and technical feasibility of several automatic control strategies. The physical-chemical processes being evaluated at Blue Plains consist of two-stage lime precipitation, recarbonation, filtration, pH control with Cl_2, CO_2 stripping, breakpoint chlorination, and granular carbon adsorption. For lime ppt, four control strategies were evaluated for directing the addition of lime. Although feed-forward alkalinity mass-loading gave the smallest deviation from the desired target, it exhibited several solid handling problems; the investigators recommend a pH plus flow proportional control system, with conductivity ratio as a backup. Similarly, pH plus flow proportional control is recommended for CO_2 during recarbonation. Among the four control modes evaluated for the filtration processes and activated carbon adsorption (head loss, influent level, programmed interval, and manual), a programmed interval gave the best performance with the lowest operating cost. Economic breakpoint chlorination requires chlorine and pH control. The Cl_2 dosage control loop employs feed-forward influent ammonia mass-loading and feedback free residual chlorine; the control loop for alkali addition (NaOH) utilizes feed-forward chlorine dosage and a feedback pH error. In the near future, direct digital control will be evaluated in Blue Plains. In addition, the process computer will perform data acquisition and alert operators to alarm conditions. With respect to economic justification, based on 1971 cost data and a 10-mgd facility, four control schemes (dosing to meet peak daily requirements, periodic operator adjustments, flow proportional dosing, and mass proportional dosing) were evaluated for alum addition for phosphorus removal and methanol addition for denitrification. Based on equal effluent quality, mass-proportional control can be economically justified.

Keywords: physical-chemical treatment, process control, instruments, automation, economic justification, and performance.

PH INSTRUMENTATION AND AUTOMATION IN THE TREATMENT OF TRADE WASTES

A. C. Stewart
Water Pollution Control, Vol. 67, No. 3, pages 265—268 (1968)

A clear description of the control instruments available and useful advice on the selection and application of neutralization agents for the control of pH are presented. The dip-type electrode system that is described is suitable for applications where the velocity of the liquid is low. The flow-type electrode system gives less trouble as the electrodes are mounted on the top of the sampling chamber. But in this, the time delay taken for the liquid to reach the electrodes is sometimes unacceptable. The paper further discusses the pH meter as a device for transforming a purely static voltage into an equivalent value of electric power. Electro-pneumatic control and electric automatic two- and three-term controls used in the pH control of the effluent are then considered. The selection and application of reagents in the pH control of the trade effluents are discussed briefly. Mention is also made of the redox controller that is used to control the oxidation-reduction reactions.

Keywords: instrumentation, automation, electrodes, industrial waste, hydrogen ion concentration, dip-type electrode, flow-type electrode, redox-controller, and reagents.

PROCESS CONTROL TECHNIQUES FOR TREATING ACID MINE-POLLUTED WATERS

Battelle Memorial Institute, Columbus, Ohio, Environmental Systems Division and Chemical Process Development Division
R. Qasim, I. L. Whitman, and R. F. Testin
Water and Sewage Works, Vol. 117, pages R240—R245 (Nov. 28, 1970)

The generalized curves and procedure presented in this paper can be applied to control the chemical feedrates and regeneration cycle of the ion-exchange resin beds in various treatment processes in municipal and industrial water treatment plants that process acid mine-polluted waters. The procedure is quite simple, since pH and specific conductance are the only parameters required for applying the curves developed in this paper. These can be monitored continuously, thereby eliminating the need for frequent chemical tests to adjust the chemical feedrates. The process of adjusting the chemical feedrates and resin beds regeneration cycle can be computerized, giving a completely automated system.

Keywords: wastewater treatment, acid mine water, industrial wastes, Appalachian Mountain region, water management (applied), industrial water, mine drainage, water pollution, streams, mine wastes, chemicals, methodology, water quality, reclaimed water, effluents, acids, neutralization, alkalinity, ion exchange, chemical analysis, data collections, and surface waters.

HOW TO SELECT A PH CONTROL SYSTEM FOR NEUTRALIZING WASTE ACIDS

F. Hoffman
Chemical Engineering, 79, 24, pages 105—110 (1972)

Pilot-plant studies should examine the important parameters for neutralization process design such as the choice of neutralizing reagent, point of application, reaction time, and adequacy of mixing. The process and load variation characteristics determine the "optimum"

pH control system. Generally, three basic types of pH control systems automatically direct the addition of neutralizing agents—batch control, continuous, and multimode controls. Small plants discharging low volumes of spent acids or bases can usually use batch neutralization. With batch control, the flow and strength can be irregular because the stored wastewater can be discharged only after the pH has been adjusted to a suitable value of range. Simple on-off feedback pH control governs the reagent addition during batch neutralization. For processes with a residence time of 5 minutes or more, an inexpensive two-position on-off feedback pH control can maintain the effluent within an acceptable range. As with other continuous neutralization control schemes, on-off control requires adequate mixing and agitation. Agitation turnover time, as a rule of thumb, should be less than 20% of residence time. Insufficient mixing causes excessive cycling and poor pH control. With high flow rates, the large high residence times required by a two-position control become impractical; this situation calls for a multimode control. The rate of the neutralizing agent addition depends upon the error between the current pH and the desired pH. The proportional plus integral mode can handle most process characteristics. Rate or derivative action is helpful in the control of process with large lags. In systems where load changes have a predictable effect, feed-forward control improves the effluent quality. Multimode control is applicable to relatively short holdup times; as a rule of thumb, from 30 seconds to 3 minutes is ideal.

Keywords: neutralization, process control, automation, load variation, batch, continuous, residence time, and feedback control.

METHANOL REQUIREMENT AND TEMPERATURE EFFECTS IN WASTE-WATER DENITRIFICATION

S. G. Dlolakia, J. H. Stone, and H. T. Burchfield
Gulf South Research Institute, U.S. Envir. Protect. Ag. Wat. Qual. Office, Wat. Pollut. Control Res. Ser. 17010DHT 09/70, U.S. Govt Printing Office, Washington, D.C., 46 pages, 50 cents (1970)

Studies have been carried out on the effect of methanol concentration and temperature on biological denitrification of sewage effluent in two types of reactor—a packed-column reactor filled with small glass beads and a suspended-growth reactor containing about 2000 mg of suspended solids per litre. For both reactors the optimal ratio of methanol to nitrate was between 2:1 and 3:1 at temperatures of 20° and 30°C, respectively, and slightly greater than 3:1 at 5°C. Temperature had only a slight effect on denitrification, and that mainly on methanol: nitrate ratios were less than optimal. Dissolved oxygen had no appreciable effect on denitrification, although the process appeared to be slightly more efficient at lower dissolved-oxygen concentrations. The packed-column reactor was more efficient than the suspended-growth reactor since it required a shorter detention period.

Keywords: denitrification, wastewater treatment, temperature, dissolved oxygen, tertiary treatment, nutrients, eutrophication, ammonia, and nitrates.

RAPID DENITRIFICATION BY THE NEGATIVE-PRESSURE PROCESS

G. Bringman and R. Kuhn
Gesundheitsingenieur, 86, pages 16—19 (1965)

A process is described for rapid denitrification in which the gas phase is withdrawn at a continuous rate from the denitrification tank under a negative pressure of 1 m water pressure, thus producing a condition which is comparable to the turbulent process (see Wat. Pollut. Abstr., 1964, 37, Abstr. No. 1322), and involving intensive removal of gas bubbles without a pumping device. Simultaneously, the negative pressure promotes the vital anaerobic action of the denitrifying bacteria. To ensure the smooth removal of gas bubbles, two PVC pipes are positioned at right angles in the direction of flow, to serve as carrier for the biological film of the denitrifying bacteria. Rapid denitrification by the negative-pressure process reduces the inorganic nitrogen by 80:3 percent during a single passage of mixed liquor without recirculation at an average retention period of 12 min. The denitrification efficiency in this process can be adapted automatically to any waste-water conditions by measurement of the oxidation-reduction potential. As in the turbulent process, the denitrification process is followed by a short period of final aeration to deodorize the denitrified effluent and to adjust the redox potential in order to satisfy the remaining BOD.

Keywords: denitrification, negative pressure, anaerobic, and redox potential.

ION EXCHANGE FOR NITRATE REMOVAL

Federal Water Quality Administration, Cincinnati, Ohio. Advanced Waste Treatment Research Lab.
R. Dobbs
In: Nitrogen Removal from Wastewaters, No. 6, 2 pages FWQA Project 17010-05/70 (May 1970)

A resin with a high selectivity for nitrate ion over other anions, comparable to the selectivity of resins used for water softening, does not presently exist. Tests conducted to provide a technical and economic evaluation of the feasibility of removing nitrates from irrigation return flow have shown that, although commercially available resins do have selectivity over chloride, the selectivity ratio must be 20 to 1 for the process to be economical. Should such a resin be developed, efficiency of sodium chloride regeneration is only 1%, and disposal of the resulting nitrate laden brine would be difficult. Reaction with ferrous sulfate and neutralization with lime would produce nitrogen gas, but chemical sludges difficult to dispose of would also result. Several research efforts are continuing, but until these obstacles have been surmounted, selective nitrate removal will remain unfeasible.

Keywords: ion exchange, separation techniques, nitrates, selectivity, anions, brine feasibility, wastewater treatment, and regeneration.

TREATMENT OF HIGH NITRATE WATERS

Federal Water Pollution Control Administration, Fresno, Calif., Dept. of Environmental Engineering
Percy P. St. Amant and Perry L. McCarty
Amer Water Works Ass 89th Annu Conf, May 21, 1969, San Diego, Calif. (1969)

Biological denitrification was investigated as an economically feasible way to remove nitrates from waters to control discharge of nutrients into bodies of water. Pilot-plant studies were conducted to estimate chemical requirements, to evaluate anaerobic filter media, and to determine the operating parameters of the anaerobic filtration process. Biological denitrification in anaerobic filters is a reliable process for removing excess nitrates from water supplies. An organic electron donor must be added to accomplish denitrification and methanol has been found to be a satisfactory and inexpensive material for this purpose. Use of one-inch gravel filter media and a detention time of one hour is sufficient for 90% or greater removal of approximately 20 mg/l of nitrate-nitrogen in water with temperature of 12 deg C and above. Costs, operating characteristics, and filter design data are tabulated.

Keywords: wastewater treatment, denitrification, anaerobic conditions, anaerobic bacteria, filtration, porous media, aeration, and anaerobic filtration treatment.

NITRATE REMOVAL FROM WASTEWATERS BY ION EXCHANGE

Dow Chemical Co., Walnut Creek, Calif.
Robert R. Grinstead and Kenneth C. Jones
Copy available from GPO Sup Doc as EP 2.10: 17010 FSJ 01/71, $1.00; microfiche from NTIS as PB-204 527, $0.95. Environmental Protection Agency - Water Quality Office, Water Pollution Control Research Series, EPA Program 17010 FSJ 01/71 (January 1971)

Alkylated amidines dissolved in an aromatic hydrocarbon were absorbed in macro-porous polystyrene beads to form a water-immiscible extractant system for the removal nitrate from wastewaters. The amidines are relatively strong bases and possess the advantage over the simple aliphatic amines that they exist in the salt form in contact with wastewaters in the pH range of 7.0 to 8.0. They can, however, be readily regenerated with alkalis, such as ammonia or sodium hydroxide. Amidinium ion in the organic phase selectivity extracts nitrate ion over chloride ion by a factor of about 20 (nitrate/chloride ratio in the organic phase is about 20 times the ratio in the equilibrium acqueous phase), and nitrate over sulfate and bicarbonate by much higher ratios. Therefore, amidine systems will pick up mainly nitrate ion from municipal wastes. Accordingly, 70 bed volumes of a synthetic municipal wastewater containing 62 ppm nitrate ion and 350 ppm chloride ion were treated before breakthrough of nitrate ion in the effluent. Processing costs were estimated currently at 16 cents/1000 gal.

Keywords: denitrification, anion exchange, nitrate, separation techniques, ion exchange, absorption, evaporation, ammonia, tertiary treatment, cost analysis, wastewater treatment, municipal wastes, resins, solvent extractions, amidines, regeneration, and sodium hydroxide.

NITROGEN RELATIONSHIPS IN BIOLOGICAL TREATMENT PROCESSES—III. DENTRIFICATION IN THE MODIFIED ACTIVATED SLUDGE PROCESS

Texas Univ., Austin, Environmental Health Engineering Research Lab
S. Balakrishman, and W.W. Eckenfelder
Water Research (J Int Assn on Wat Pol Res), Vol. 3, No. 3, pages 177—188
(March 1969)

A laboratory model of modified activated sludge units under both batch and continuous feed conditions was used to study the denitrification of wastewater. The separated sludge is held under anaerobic conditions to require the bacteria to use the oxygen from nitrates and accomplish denitrification. Rate of denitrification increased as the organic matter by TOC increased. Higher denitrification rates accompanied higher nitrate concentrations in the sludge. The presence of oxygen at a level of 6.0 mg/1 prevents denitrification. A 4-hr detention at 25 deg C removed 80-90% of the total nitrogen. The process used is Contact-Stabilization-Denitrification.

Keywords: denitrification, nitrogen, nitrates, oxygen, carbon, trickling filter, activated sludge, microbial denitrification, TOC, MLSS, contact-stabilization-denitrification, batch flow, continuous flow, anaerobic and COD.

AN INVESTIGATION OF THE EFFECTS OF RESIDENCE TIME ON ANAEROBIC BACTERIAL DENITRIFICATION

California Univ., Davis
Stephen F. Moore, and Edward W. Schroeder
Water Research, Journal of the International Association on Water Pollution Research, Vol. 4, No. 10, pages 685—694 (October 1970)

A bench-scale laboratory apparatus was utilized in the study of the effect of residence time on cell yield and reaction rates in anaerobic bacterial denitrification. The contents of the reactor were assumed to be completely mixed, to be at or near steady state, and to follow first order kinetics with respect to cell growth. Analysis of the data obtained from the reactor revealed that (1) complete mixing is essential for optimal removal of nitrate in bacterial denitrification ponds, and (2) batch studies do not adequately model a continuous flow system. Also, bacterial denitrification was greatly influenced by the bacteriology, largely a function of the rate and composition of the feed. At optimum hydraulic and organic conditions, then, there existed also an optimum residence time which was determined to be 6 days for the waste and the conditions in this particular study. Nitrate buildup, reported to be a problem in earlier work, was not observed to be a problem in a completely mixed, continuous flow reactor.

Keywords: denitrification, anaerobic conditions, nitrogen, phosphorus, microorganisms, physiology (animal), cost analysis, hydrogen ion concentration, wastewater treatment, anaerobic bacteria, residence time, washout, complete mixing, methanol, and batch studies.

EVALUATION OF ANAEROBIC DENITRIFICATION

Metcalf and Eddy, Inc., Palo Alto, Calif.
D. F. Seidel and R. W. Crites
Journal of the Sanitary Engineering Division, Proceeding of the ASCE, Vol. 96, No. SA 2, pages 267—277 (April 1970)

Several methods of removing nitrogen from sewage effluents by anaerobic denitrification were evaluated. An upflow anaerobic filter containing gravel media (1 in. to 1.5 in.) was used to denitrify a municipal wastewater which contained an average of 14 mg/l nitrate nitrogen. Results obtained from pilot plant studies using methanol as a supplementary carbon source for the denitrifying bacteria showed 90% nitrogen removal with a detention time as short as 1.5 hours. Laboratory studies were also conducted utilizing upflow and horizontal flow filters containing a fiber media composed of a Dynel fiber coated with neoprene resin and bonded to a fiberglass mesh. This highly porous fiber media performed comparably to the gravel media in the upflow filter as 88% nitrate nitrogen removal was obtained with a detention time of 2 hours. However, media configuration and poor flow distribution limited the success of the horizontal flow filters. Several advantages of the anaerobic filter process for denitrification, such as low initial and operating cost, simplicity of operation, long solids retention times, and absence of any sludge recycle or disposal equipment were presented. The cost of methanol was the major operating expense for the process. The quantity of methanol required increases with increasing dissolved oxygen and nitrate nitrogen and decreasing effluent BOD. The total cost not including the cost of nitrifying the secondary effluent and reaerating the denitrified effluent was estimated as low as $12.00 per million gallons.

Keywords: anaerobic digestion, denitrification, filters, pilot plants, laboratory test, anaerobic bacteria, nitrates, wastewater treatment, sewage treatment, waste treatment, upflow, horizontal flow, and media.

NITRATE REMOVAL FROM ACTIVATED SLUDGE SYSTEMS

Washington Univ., Seattle, Dept. of Civil Engineering
Dale A. Carlson
Available from NTIS as PB-194 457, $3.00 in paper copy, $0.65 in microfiche. Completion Report, OWRR Project A-026-WASH (1) (July 15, 1970)

Pilot plant studies of nitrification-denitrification in activated sludge facilities treating domestic waste waters provided equations and printouts for design of nitrification and denitrification units. For nitrification tank design, a computer program and printouts were developed which present the equation in graphical form to facilitate use. The equation printouts provide minimum retention times necessary to achieve consistent nitrification. The oxygen requirement for full nitrification was 4 mg/l and the percent nitrification dropped with loading factors above 0.2 lb BOD 5 per day per pound of mixed liquor suspended solids. In the denitrification unit the percent nitrate removal diminished with increasing dissolved oxygen supporting the theory that complete anaerobiosis is necessary for maximum denitrification. The rate of nitrate removal was directly dependent on the mixed liquor volatile suspended solids concentration of the denitrifying. The denitrification equation developed defines the minimum sludge concentration necessary for complete reduction of nitrates. While the constants in the equation solutions are based on all weather conditions in the Pacific Northwest, a method for evaluating equation constants provides the means of applying the equation to any location.

Keywords: nitrification, denitrification, water quality control, eutrophication, activated sludge, wastewater treatment, and nitrate removal.

NITRIFICATION AND DENITRIFICATION OF WASTEWATER

Minnesota Univ., Minneapolis, Sanitary Engineering Division
Walter K. Johnson and George B. Vania
Available from the National Technical Information Service as PB-202 350, $3.00 in paper copy, $0.95 in microfiche, Minnesota University, Sanitary Engineering Report No. 1755, 52 ref. FWQA Prog. 17010 FMX 01/71, Grant No. WP01028 (January 1, 1971)

The denitrification portion of this work was accomplished by continuous flow reactor, a gravity solids-liquid separator, and sludge recycle. A portion of the raw wastewater was added as an external carbon source. By operating two completely mixed biological reactors in series it was possible to accomplish both nitrification and denitrification. Aeration times of 7-9 hours were used to produce a completely nitrified effluent at temperatures as low as 10-12°C. Denitrification was accomplished with a 1.3 hour mean reaction tank detention time at 20°C and in 2.6 hours at 10°C. Effluent ammonia nitrogen was that amount which was added to provide a carbon source. Therefore, addition of wastes with little or no ammonia nitrogen as a carbon source would produce an effluent nearly devoid of ammonia nitrogen. The BOD to nitrogen ratio was shown to be the critical parameter, inasmuch as high ratios would produce a high effluent carbon content, and low ratios resulted in complete denitrification. Keeping the ratio constant resulted in an effluent nitrogen concentration well below 1.0 mg/1. By this same analysis, the rate of nitrate reduction was shown to be a linear function of the sludge loading rate.

Keywords: nitrification, denitrification, activated sludge, municipal wastes, ammonia, nitrogen, nitrates, eutrophication, temperature, flow rate, biochemical oxygen demand, sludge, wastewater treatment, tertiary treatment, BOD to nitrogen ratio, and suspended solids.

AUTOMATION AND CONTROL OF PHYSICAL–CHEMICAL TREATMENT FOR MUNICIPAL WASTEWATER

EPA, NERC, Advanced Waste Treatment Research Lab., Cincinnati, Ohio
J.J. Convery, J.F. Roesler, and R.H. Wise

Proceedings of International Conference on Water Pollution Research and American Institute of Chemical Engineers, Vanderbilt University (Sept. 18–22, 1972)

The Blue Plains pilot plant in Washington, D.C., is being used to evaluate the economic and technical feasibility of several automatic control strategies. The physical-chemical processes being evaluated at Blue Plains consist of two-stage lime precipitation, recarbonation, filtration, pH control with Cl_2, CO_2 stripping, breakpoint chlorination, and granular carbon adsorption. For lime precipitation, four control strategies were evaluated for directing the addition of lime. Although feed-forward alkalinity mass-loading gave the smallest deviation from the desired target, it exhibited several solid handling problems; the investigators recommend a pH plus flow proportional control system, with conductivity ratio as a backup. Similarly, pH plus flow proportional control is recommended for CO_2 during recarbonation. Among the four control modes evaluated for the filtration processes and activated carbon adsorption (head loss, influent level, programmed interval, and manual), a programmed interval gave the best performance with the lowest operating cost. Economic breakpoint chlorination requires chlorine and pH control. The Cl_2 dosage control loop employs feed-forward influent ammonia mass-loading and feedback free residual chlorine; the control loop for alkali addition (NaOH) utilizes feed-forward chlorine dosage and a feedback pH error. In the near future, direct digital control will be evaluated in Blue Plains. In addition, the process computer will perform data acquisition and alert operators to alarm conditions. With respect to economic justification, based on 1971 cost data and a 10-mgd facility, four control schemes (dosing to meet peak daily requirements, periodic operator adjustments, flow proportional dosing, and mass proportional dosing) were evaluated for alum addition for phosphorus removal and methanol addition for denitrification. Based on equal effluent quality, mass-proportioned control can be economically justified.

Keywords: physical-chemical treatment, process control, instruments, automation, economic justification, and performance.

KINETIC STUDIES OF DENITRIFICATION BY PSEUDOMONAS DENITRIFICANS

Washington University, Seattle
Won Hong Lee
Master's Thesis (Aug. 1971)

Laboratory scale tests were performed on organisms grown in batch reactors to obtain data on the kinetics of denitrification by pseudomonas denitrificans. Use of a manometer allowed the pressure changes caused by the nitrification to be measured, after correction for atmospheric pressure variations. Sodium acetate was used as substrate, and the amount of N2 gas liberated from each substrate concentration was measured and plotted N2 produced versus sodium nitrate produced per hour. The rate of denitrification was demonstrated to follow the Michaelis pattern, not being inhibited by high substrate concentration.

Keywords: kinetics, denitrification, laboratory tests, nitrogen cycle, nitrification, instrumentation, manometers, pressure, solubility, temperature, mixing, inhibition, anaerobic conditions, wastewater treatment, reaction rates, and pseudomonas denitrificans.

Bernstein and E. Fein

COMPUTER CONTROL OF PHYSICAL-CHEMICAL WASTEWATER TREATMENT

D. F. Bishop, W.W. Schuk, R.B. Samworth, R. Bernstein, and E. Fein

Presented at 1st International Meeting of Society of Engineering Sciences, Tel Aviv, Israel (June 1972)

Advanced waste treatment systems in the EPA D.C. pilot plant include: 1) an analog-automated physical-chemical treatment system, applied directly to remove solids and phosphorus, 2) filtration to remove residual turbidity, 3) chlorination with pH control to remove ammonia, and 4) granular carbon adsorption to remove soluble organics. The pilot plant typically reduces the residual pollutants to 5 mg/l of BOD, 15 mg/l of COD, 0.15 mg/l of phosphorus, and 2.6 mg/l of total nitrogen. The control objective in the plant is to produce the best possible quality of wastewater effluent with minimum chemical usage. The controlled variables include flow rate, organic concentrations, alkalinity, pH, NH_3, PO_4, and residual-free chlorine concentrations. An IBM digital computer system (System/7) with flexible hardware and software was designed for the pilot plant. The process control computer also included a data acquisition and alarm monitoring function on other pilot systems by collecting plant data from approximately 80 wastewater process sensors. Control algorithms were developed from analyses of the plant characteristics, including the existing sensors and actuators. The IBM System/360 Continuous System Modeling Program was used to simulate the plant under digital computer control and provided predictive performance data, using the designed control algorithms on the simulated plant. The simulation analysis included a sensitivity analysis to determine controlled plant response characteristics under conditions of uncertainties or errors in knowledge of plant parameters. The existing analog-controlled plant was simulated to provide relative performance information and to verify the plant model. The control algorithms developed and verified in this work will be programmed, tested, and implemented on the actual pilot plant with an IBM System/7 computer.

Keywords: instrumentation, automatic control, DDC, algorithms, simulation, data acquisition, sensitivity, wastewater, and physical-chemical treatment.

INVESTIGATION OF THE USE OF HIGH PURITY OXYGEN AERATION IN THE CONVENTIONAL ACTIVATED SLUDGE PROCESS

Union Carbide Corporation, Tonawanda, N.Y., Linde Division
J.G. Albertsson, J.R. McWhirter, E.K. Robinson, and N.P. Vahldieck
Available from the NTIS as PB-194 241, $3.00 in paper copy, $0.65 in microfiche. Federal Water Quality Administration Water Pollution Control Research Series (May 1970)

A full-scale system designed to demonstrate the practical and economical use of high purity oxygen gas in aeration of the conventional activated sludge waste treatment process was tested under a variety of operating conditions in a direct performance comparison with a parallel air-aerated system. A sparged-turbine gas-liquid contacting unit was employed in covered tanks of conventional design with liquid and gas staging for concurrent flow of each phase. This oxygenation system required very low power input for oxygen transfer and liquid mixing. The oxygenation system could operate with MLVSS concentrations of as high as 4500 mg/liter, achieving about 90% BOD removals at aeration detention times as low as 1.2 hours (raw flow + recycle flow) treating domestic waste of 220 mg/liter BOD. Biomass from the oxygenation system is highly flocculent and readily settleable with desirable handling characteristics. Recycle and waste activated sludge suspended solids concentrations of about 3% were achieved. Process advantages recognized with the oxygenation system indicate significant reductions in secondary waste treatment cost in comparison to conventional diffused air-aerated systems.

Keywords: sewage treatment, activated sludge, oxygenation, aerobic treatment, sludge digestion, sludge treatment, oxidation, and sludge oxygenation.

DETROIT AIMS FOR SAVINGS WITH PURE OXYGEN AERATION

Detroit Metro Water Department, Mich.
G. Remus, D. Suhre, and G. Hubbell
Paper presented at the Annual Conference, Water Pollution Control Federation, San Francisco, 16 pages (Oct. 3-8 1971)

The Detroit Metro Water Department constructed $220 million of water pollution control works, and the City planned $193 million more in 1972. An additional $400 million of capital expenditures is planned by the end of 1979. Sewage disposal of the Detroit Metropolitan area is handled by a single interceptor system and a single treatment plant. In meeting commitments to provide sewage disposal service for the entire metropolitan area, with minimum land requirements and without demolishing usable residences in the area, studies were made of means of optimizing bacterial action by using pure oxygen aeration to support the activated sludge process. In February 1971, construction began on a two-tank aeration module that will consist of one tank of 150 mgd capacity on the deep tank, high rate, air-aerated process, and a 300 mgd tank on the oxygenated activated sludge process. The operation was scheduled for February 1973. An additional 600 mgd oxygenation facility is planned to be put into operation in

1976. All in all, as compared to conventional activated sludge, Detroit is aiming for savings far in excess of the $2.50/mil gal expected to be realized with the oxygenated activated sludge. Early estimates are that, on a plant-wide basis, overall operating and capital costs will have been trimmed by $21.35/mil gal through innovative design features.

Keywords: oxygenation, aeration, sewage treatment, wastewater treatment, activated sludge, Michigan, Lake Erie, water pollution control, treatment facilities, cost-benefit analysis, biochemical oxygen demand, bacteria , aerobic treatment, sanitary engineering, and sludge treatment.

PHOSPHORUS REMOVAL FROM WASTE WATER BY DIRECT DOSING OF ALUMINATE TO A TRICKLING FILTER

E. F. Barth, B. N. Jackson, R. F. Lewis, and R. C. Brenner
J. Water Pollution Control Fed., pages 1932—1942 (1969)

Full-scale studies were carried out at the sewage works in Fairborn, Ohio, on removal of phosphorus from sewage by direct application of sodium aluminate to the low-rate percolating filters, resulting in precipitation of aluminum phosphate on the surface of the filter medium. Results of the studies, summarized in tables and graphs, showed that this method is effective in removing phosphorus and has no harmful effects on the efficiency of the filter or on the biological slime. It is pointed out, however, that phosphorus removal by this method is not as efficient as the addition of aluminate to an activated-sludge tank, since a certain amount of short circuiting is likely to occur in rock media filters, and the contact between sewage and active film is less than in the activated-sludge process.

Keywords: phosphates, sewage, sodium aluminate, trickling filter, short circuit and analytical technique.

TREATMENT TECHNIQUES FOR REMOVING PHOSPHORUS FROM MUNICIPAL WASTE WATERS

Environmental Protection Agency, Cincinnati, Ohio, Environmental Research Lab.
J. J. Convery
Available from GPO, Sup Doc as EP2.10:17010—01—70, $0.50; microfiche from NTIS as PB-199 072, $0.95. EPA Report 17010—01-70, 35 pages (Jan. 1970)

Biological uptake, chemical precipitation of soluble phosphorus, and settling or filtration of particulate phosphorus are the major removal mechanisms used in phosphorus removal. At present, chemical precipitation is the most universally applied method. The wide variety of chemical reagents that lead to phosphorus precipitation allows much flexibility of operation to plant operators. In dealing with raw sewage, primary effluent, or secondary effluent, the size of the plant, influent wastewater characteristics phosphorus discharge standard, and the types of other processes used in the treatment train must all be considered. In addition to phosphorus removal, higher levels of BOD and suspended solids removals are customarily obtained when some type of phosphate reduction mechanism is employed. Each of the mechanisms described here has been analyzed with respect to both technological and economic feasibility. Costs ranged from $0.13/1000 gallons for two-stage lime treatment of 1 mgd to achieve 97% removal, to a potential low of $0.-15/1000 gallons using waste pickle liquor to achieve a reduction of 80%.

Keywords: phosphates, filtration, chemical precipitation, coagulation, sedimentation, lime, alkalinity, hydrogen ion concentration, neutralization, turbidity, flexibility, tertiary treatment, cost analysis, economic feasibility, and wastewater treatment.

PHOSPHORUS REMOVAL BY CHEMICAL ADDITION DURING SECONDARY TREATMENT

R. C. Brenner

Proceedings, Pittsburg Sanitary Engineering Conference, 8th, Pittsburg, Pa. (Feb. 1970)

A description of mineral addition to an activated sludge system is presented. The alternative application points are: primary effluent, mixed liquor, exit to clarifier, sludge recycle, and raw sewage. The chemical additives are aluminum salts and iron salts. Low capital expenditure, reduction of liquor settling characteristics, and reduction of effective organic loading are some of the advantages of mineral addition to the secondary system. Comparison of iron and aluminum, aluminum sulfate and sodium alum aluminite are listed. Some of the side effects of mineral additions are: alum and ferrous and ferric sulfate introduces sulfate ions to the system, while aluminate introduces sodium ions. The results of pilot and full-scale experiments indicate that aluminate is better suited to low to moderately low alkaline wastewater, while alum and iron compounds are better suited to moderately high to highly alkaline wastewater. Recommendations for a site of phosphorus removal for the following plants: primary sedimentation, trickling filter, activated sludge, and advanced waste treatment, are listed.

Keywords: phosphorus, mineral, activated sludge, effluents, sludge, sewage, organic loading, iron, aluminum, alkalinity, trickling filters, sedimentation, and wastewater treatment.

FACTORS THAT AFFECT ACTIVATED-SLUDGE PHOSPHATE RELEASE

C. W. Randall, B. S. Hulcher, and P. H. King

Water Resources, Bulletin 6, pages 648—660 (1970)

In a laboratory study of the factors affecting the release of soluble phosphate from activated sludge, the effects of oxidation-reduction potential, dissolved oxygen, pH value, solids concentration, solids destruction, and sulphate addition were investigated, as well as the effect of substrate utilization on phosphate uptake and the relation between uptake characteristics and subsequent phosphate release. Under aerobic conditions the rate of uptake of phosphate was slightly faster than the removal of COD during the early stage of stabilization and less in the later stage, indicating that some phosphate storage occurred. Under induced anoxic conditions, the rapid release of soluble phosphate occurred; this release was not a function of a change in oxidation-reduction potential or in pH value, but was primarily based on cell lysis.

Keywords: phosphate, solubility, rates, and cell lysis.

PHOSPHORUS REMOVAL IN TRICKLING FILTERS

H. J. Jebens

Thesis, University of Wisconsin, Diss. Abstr., 31, B, pages 6655—6656 (1971)

To relate the removal of phosphorus in percolating filters to the parameters of hydraulic load, depth, recirculation, and strength of wastewater, factorial experiments were carried out in September—December 1969 at the Madison Nine Springs waste treatment plant, using controlled dilutions of sewage in four 12-ft deep pilot-scale filters containing Flocor medium. Composite samples were obtained at 2-hour intervals for each 4-ft depth of the filter. Analytical results showed that the reductions in BOD were correlated with the hydraulic load, depth of filter, and degree of recirculation, but not with the strength of the sewage; the removals of BOD could be described by mathematical models in the literature and were in close agreement with the Germain and Eckenfelder equations. Reductions in the concentration of phosphorus could not, however, be correlated with any of the parameters, but the removal of phosphorus was consistently higher than could be accounted for by microbial requirements. The analysis of slime from the filters indicated that orthophosphate had been precipitated with calcium and possibly with iron and aluminium. Further studies were subsequently made on the slime: 1) in March 1970, experiments on the release of phosphorus suggested that the orthophosphate might be combined with calcium as an apatite and with iron as ferric phosphate; and 2) in June 1970, X-ray diffraction studies revealed trace amounts of aluminum phosphate with calcium carbonate as a crystalline precipitate. It is concluded that the high degrees of removal of phosphorus in percolating filters were the result of a mechanism comparable with the "enhanced removal" of phosphorus previously reported in some activated sludge plants.

Keywords: phosphorous, calcium, iron, and trickling filter.

REMOVAL OF ORTHOPHOSPHATES FROM AQUEOUS SOLUTIONS WITH ACTIVATED ALUMINA

Northwestern University, Evanston, Ill., Department of Chemical Engineering
R. D. Neufeld and G. Thodos
Environmental Science and Technology, Vol. 3, No. 7, pages 661—667 (July 1969)

The authors cite evidence that some biological treatments for the reduction of phosphates in wastewater treatment (involving the use of activated sludge or algal removal in a controlled environment) do not fulfill rigid requirements for tertiary treatment. Utilizing laboratory-scale fixed beds of activated alumina ranging from 1.97 to 26.0 centimeters in height, they effected removals in excess of 99.9% orthophosphates from aqueous solutions. Initial concentrations of phosphate-ion in feed varied from 10 to 120 milligrams/liter. Experimental evidence indicates that an exchange with nitrates present on solid alumina accompanies the initial removal of orthophosphates, followed by the consecutive reaction of phosphate on the surface with that in solution to effect further removal.

Keywords: phosphorus compounds, eutrophication, nitrates, ion exchange, water pollution control, wastewater treatment, nutrients, analytical techniques, adsorption, water chemistry, sorption, hydrogen ion concentration, orthophosphates, chemical processes, activated alumina, alumina, surface chemistry, colloidal chemistry, langmuir isotherm, and probability plot.

PHOSPHATE REMOVAL BY pH CONTROLLED LIME DOSAGE

Anne Arundel County, Department of Public Works, Glen Burnie, Md.
G. Spohr and A. Talts
Public Works, Vol. 101, No. 7, pages 63—66 (July 1970)

Phosphates can be removed from wastewaters by either of two generally different approaches, a tertiary stage of chemical precipitation and removal or a combined chemical-biological process. The cost advantages of the second approach have prompted a great deal of study in this area. A program has been undertaken to evaluate the potential applications of these phosphate removal processes to specific secondary treatment plants. Initial jar-testing considered all possible chemical additives, lime, aluminum salts, iron salts, and polymers. A full-scale plant test was conducted at the Patuxent River Basin wastewater treatment plant of a pH controlled lime dosage system for phosphate removal. The conclusions of this test were: 1) lime slurry addition to wastewater prior to primary sedimentation can be effectively accomplished, 2) total phosphate removal is possible and practical by using this process, the efficiency of removal being based on the characteristics of the raw sewage and lime dosage, 3) suspended solids, BOD, and COD are reduced in proportion to the lime dosages, 4) the limitations of this process are established by the adaptability of the biological treatment stage, and 5) further study, using other chemicals, should be initiated to avoid the limitations in 4 above. Tertiary treatment is warranted if these limitations cannot be circumvented.

Keywords: wastewater treatment, phosphates, lime, iron compounds, aluminum, hydrogen ion concentration, biochemical oxygen demand, chemical oxygen demand, turbidity, tertiary treatment, automatic control, removal, and suspended solids.

FACTORS INFLUENCING PHOSPHORUS REMOVAL BY BIOLOGICAL TREATMENT

Federal Water Quality Administration, Cincinnati, Ohio
R. L. Bunch
Chemical Engineering Progress, Symposium Series, Vol. 67, No. 107, pages 90—94 (1971)

In recent years the phosphate content of wastewater treatment plant effluents has been rising, presumably traceable to the use of phosphates in detergents. Conventional biological treatment does not effectively remove nutrients from wastewater. The influence of an increased use of phosphates, digester recycle, and imbalance of nutrients in wastewater was recently studied. Phosphorus removal by synthesis can be higher than normally encountered if digester supernatant is not recycled and primary clarification is eliminated. The elimination of these two practices will increase the carbon to phosphorus ratio, thereby correcting the nutrient imbalance. If phosphorus is to be removed from wastewater on a sustained basis, then chemical or chemical-biological methods must be used, and efforts must be continually made to improve the dependability and applicability of the biological process.

Keywords: biological treatment, phosphorus, wastewater treatment, nutrients, synthesis, sludge, effluent, algae, secondary treatment, biochemical oxygen demand, chemical oxygen demand, carbon, fertilization, dissolved oxygen, sewage, hydrogen ion concentration, and suspended solids.

ANOXICALLY-INDUCED RELEASE OF PHOSPHATE IN WASTE-WATER TREATMENT

L. Shapiro, G. V. Levin, and H. Zeal
J. Water Pollution Control Fed., pages 39, 1810—1818 (1967)

During studies at the sewage works in Baltimore, Md., upon removal of phosphorus from sewage by activated sludge, it was found that, although the concentration of soluble phosphate was reduced during aeration, the effluent from the secondary sedimentation tank frequently contained higher concentrations of phosphate than did the effluent from the aeration tanks. This indicated that a considerable amount of the phosphate taken up by the sludge was leaking out of the cells during sedimentation. Further studies on the distribution of phosphate in the sedimentation tank indicated that the release of phosphate was stimulated by low dissolved-oxygen concentrations and/or oxidation-reduction potentials, and laboratory experiments were begun to investigate conditions affecting the release of phosphate, including stirring, temperature, and solids concentration. The results suggest that redox potential is more important than oxygen concentration in controlling phosphate release; the phenomenon is completely reversible, and the phosphate is taken up again when the sludge is aerated. The release of phosphate is stimulated by stirring and by increase in temperature, but is independent of external phosphate concentration. Only orthophosphate is released, and apparently mostly from an acid-soluble fraction of the sludge cells. The release of phosphate is also stimulated by high concentrations of cyanide and mercury. To avoid the release of phosphate from the sludge, it is important to maintain high oxygen concentrations and redox potentials during sedimentation or to use mechanisms that separate the sludge and supernatant liquor rapidly. It is suggested, however, that use could be made of this phenomenon to release phosphate from the sludge and then re-absorb it into a small volume of sludge that could be disposed of, while the remaining phosphate-depleted sludge would be returned to the aeration tanks.

Keywords: phosphate release, ORP, dissolved oxygen, sludge, sedimentation, and orthophosphate.

CHEMICAL-BIOLOGICAL CONTROL OF NITROGEN AND PHOSPHORUS IN WASTEWATER EFFLUENT

Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, Cincinnati Water Research Lab.
E. F. Barth, R. C. Brenner, and R. F. Lewis

J. Water Pollution Control Federation, Vol. 40, No. 12, pages 2040—2054 (Dec. 1968)

A treatment sequence has been developed that removes approximately 90% of the influent COD, SS, nitrogen, and phosphorus. The modular process consists of high-rate activated sludge, nitrification, and denitrification integrated into a single continuous-flow treatment plant. Each of the three biological unit operations has its own recycle system, so enriched cultures of microorganisms develop. Chemical control is by use of ionic aluminum and methyl alcohol. Data collected on a 185-gpd (700—1/day) pilot plant show the removal of 85% COD, 95% SS, 91% nitrogen (all forms), and 92% total phosphorus.

Keywords: waste treatment, nitrogen, phosphorus, biological treatment, sewage effluents, wastes, wastewater (pollution), wastewater treatment, flow, chemical oxygen demand, water quality, water chemistry, chemical waste-processing control, nitrogen removal, and phosphorus removal.

EFFECTIVE PHOSPHORUS REMOVAL BY THE ADDITION OF ALUM TO THE ACTIVATED SLUDGE PROCESS

Metropolitan Sanitary District of Greater Chicago, Ill.
D. R. Zenz and J. R. Pivnicka

Paper presented at the 24th Annual Purdue Industrial Wastes Conference, 59 pages (May 6—8, 1969)

The objective of this experimental research was to evaluate, under actual wastewater treatment plant operating conditions, a combined chemical-biological process capable of producing an effluent low in phosphorus, BOD, and suspended solids. Tests were conducted at the Hanover Park Water Reclamation plant in Cook County, Illinois. The plant consists of a 2-mgd conventional activated-sludge facility and a tertiary facility capable of treating the entire flow from the secondary facility. The secondary plant was separated into two distinct systems for the tests. Alum was added to the influent of the aeration tank of one system by a feed pump. Effluent samples, taken automatically as 24-hour composites, were analyzed for BOD, SS, VS, percent total solids, percent volatile solids, alkalinity, SVI, and NH3-N. An autoanalyzer was used for phosphorus determinations. It was found that the process can produce effluent phosphorus concentrations of 2.30 mg/l (total P) and 0.83 mg/l (soluble P) at an Al: total P ratio (molar basis) of 1.54 and an Al: soluble P ratio of 1.85. This is 83 and 93% removal, respectively. Bound phosphorus was not released during anaerobic digestion. The additions of large amounts of alum did not adversely affect BOD removal efficiency, but did remove higher microbial life forms in the mixed liquor. Suspended solids increased at an alum concentration of 252 mg/l, waste sludge increased, and SVI decreased. Alum did not upset the anaerobic biological treatment process.

Keywords: phosphorus, phosphates, phosphorus compounds, chemical precipitation, chemical degradation, biological treatment, biodegradation, biochemistry, biochemical oxygen demand, wastewater treatment, water pollution control, eutrophication, algal control, tertiary treatment, suspended load, pilot plants, activated sludge, treatment facilities, phosphorus removal, alum, aluminum sulfate, activated sludge process, and Hanover treatment plant.

PHOSPHATE REMOVAL BY A LIME-BIOLOGICAL TREATMENT SCHEME

Kansas State University, Manhattan; and Kansas University, Lawrence
L. A. Schmid and R. E. McKinney

J. Water Pollution Control Federation, Vol. 41, No. 7, pages 1259—1276 (July 1969)

A process based on laboratory studies is proposed for the removal of phosphorus from domestic wastewater by lime treatment of effluent by a high-rate, complete mix activated sludge process. This treatment allows for partial removal of the phosphorus by the lime with the activated sludge organisms removing the remaining portion by synthesis into cell mass. The addition of 150 mg/l calcium hydroxide to raw waste-water resulted generally in a pH of 9.5 phosphate removals of 80 percent, BOD removals of 60 percent, and SS removals of 90 percent. The activated sludge process was found to operate satisfactorily on the lime-treated wastewater, and microbial production of carbon dioxide in the activated sludge unit was sufficient to maintain a pH near neutral in the aeration compartment.

Keywords: biological treatment, phosphorus, lime, phosphates, costs, nutrients, wastewater treatment, cell synthesis, lime regeneration, sludge production, and pH.

METHOD FOR THE REMOVAL OF SOLUBLE PHOSPHATES IN WASTE WATER TREATMENT

Allied Chemical Corp., New York
J. C. Eck and W. C. Zegel
U.S. Patent 3,453,207, 5 pages (July 1, 1969)

This invention relates to the precipitation of dissolved phosphate ion in water by a combination of alum and a cationic organic latex followed by separation of the substantially free water from the phosphate-containing precipitate. Synthetic cationic organic latex contemplates a water-based emulsion formed by a free radical emulsion polymerization of 2-carbon to 30-carbon olefins, 4-carbon to 30-carbon dienes and halogen, ester or aryl substituted olefins or dienes of the above chain length or mixtures thereof with each other in water and a cationic organic emulsifying agent. The only limitation imposed is that the resultant polymer or copolymer must be water soluble. Preferable compounds for the preparation of the lattices, along with several illustrative examples, are described. Data from 17 runs indicates that the treatment of wastewater by the simultaneous addition of 10 ppm of a variety of lattices and 40 ppm of alum is as effective at removing dissolved phosphate as treatment with 150 ppm of alum alone. The treatment of wastewater with cationic latex effects essentially no phosphate removal. Treatment with 40 or 50 ppm of alum alone is significantly less effective than treatment with the synergistic combination of 40 ppm of alum and 10 ppm of latex.

Keywords: wastewater treatment, phosphates, cation exchange, emulsifiers, patents, alum, soluble phosphates, synthetic cationic organic latex, polymerization, olefins, dienes, halogen, and copolymerization.

KINETICS AND MECHANISM OF PRECIPITATION AND NATURE OF THE PRECIPITATE OBTAINED IN PHOSPHATE REMOVAL FROM WASTE WATER USING ALUMINUM (III) AND IRON (III) SALTS

Atomics International, Canoga Park, Calif.
H. L. Recht and M. Ghassemi
For sale by the Superintendent of Documents, U.S. GPO, Washington, D.C. 20402. 17010 EKI 04/70 paper copy $0.75. Available from NTIS as PB-196 737, $0.95 in microfiche. Water Pollution Control Research Series 17010 EKI-04/70, Advanced Waste Treatment Research Lab., Cincinnati, Ohio, 77 pages (April 1970)

An investigation was conducted of the rate, mechanism, and stoichiometry of phosphate precipitation with aluminum and ferric salts from pure phosphate solutions and secondary effluent. These studies showed that the reactions of orthophosphate ion with both Al (III) and Fe (III) are completed in less than 1 second. The effects of pH, reactant concentration, and reagent aging on the efficiency of phosphate removal were evaluated in batch precipitation experiments. The pH of optimum orthophosphate precipitation was found to be close to 6.0 for Al (III) and in the vicinity of 3.5 to 4.0 for Fe (III). With an initial orthophosphate

concentration of 12 mg/l P, maximum phosphate removal was about 82% with Fe (III) and about 78% with Al (III) at a 1:1 molar ratio, increasing to over 99% for both cations at a 2:1 ratio. At constant pH, with both Fe (III) and Al (III) up to about a 1:1 molar ratio, orthophosphate removal was directly proportional to the amount of added cation, indicating the occurrence of a chemical reaction. Diluted solutions of Fe (III) were found to undergo extensive hydrolysis on aging, with a resultant loss of the capacity to precipitate phosphate. The removal of condensed phosphates by precipitation with aluminum and iron salts was found to be strongly dependent on pH and the reactant concentration ratio. Precipitates obtained in the reaction of orthophosphate with aluminum and ferric salts were examined by X-ray diffraction analysis after drying and heating to 104° C and 600° C. Both precipitates remained amorphous, except that ferric phosphate was identified after ignition at 600° C.

Keywords: phosphates, kinetics, aluminum, iron, wastewater treatment, chemical precipitation, effluents, chemical reactions, phosphate removal, aluminum salts, iron salts, orthophosphates, and secondary effluents.

RELEASE OF SOLUBLE ORTHO-PHOSPHATE IN THE ACTIVATED SLUDGE PROCESS

Kurita Central Labs., Yokohama (Japan)
Y. Sekikawa, S. Nishikawa, M. Okazaki, and K. Kato

Proceedings of the 3rd International Conference on Water Pollution Research, Munich, Germany, pages 261—276 (1966)

During periods of unfavorable growth conditions (such as nutrient deficiency, low dissolved oxygen concentration, or the presence of toxic or inhibitory materials), activated sludge cultures will release orthophosphate back into the solution. This conclusion, supported by data presented in the figures and tables, suggests that phosphate variation might serve as an indicator of the physical condition of a biological treatment process. The measurement of phosphate concentration on a continuous basis will provide the plant operator with information as to how well the process is faring in regards to whether the microorganisms are working in as favorable an environment as possible. Further studies under more complicated operating conditions are necessary in order to more fully understand the physical parameters of the system that are directly related to the change in phosphate concentration, and also those that are directly affected by the conditions which cause variations in the phosphate concentration.

Keywords: phosphorus compounds, activated sludge, microorganisms, industrial wastes, metabolism, disinfection, phenols, poisons, biochemical oxygen demand, wastewater treatment, aerobic treatment, sludge treatment, orthophosphorus compounds, orthophosphates, aerobic digestion, Warburg respirator, manometric apparatus, sludge volume index, volatile suspended solids, mixed liquor, aldehydes, and endogenous respiration.

DISCUSSION OF "RELEASE OF SOLUBLE ORTHO-PHOSPHATE IN THE ACTIVATED SLUDGE PROCESS"

Illinois University, Urbana
R. C. Engelbrecht
Proceedings of the 3rd International Conference on Water Pollution Research, Munich, Germany, pages 276–280 (1966)

The level of phosphorus in an activated sludge tank has been proposed as an indicator of the activity of the microorganisms in the system. Much variation in phosphorus uptake has been observed in various parts of the world. Phosphorus uptake in excess of normal requirements for biosynthesis is the subject of much debate. Luxury uptake, storage, synthesis of ATP, and adsorption onto the floc are a few of the mechanisms proposed to explain this excess uptake. Regardless of what mechanism causes the uptake, methods of continually monitoring the phosphorus content in the raw sewage, in the areation tank, and in the effluent are necessary before any application of the phosphorus level as an indicator of biological treatment becomes practical.

Keywords: orthophosphorus compounds, nitrogen, slimes, adsorption, eutrophication, dissolved oxygen, aeration, biochemical oxygen demand, activated sludge, wastewater treatment, luxury uptake, assimilation, adenosine triphosphate, biosynthesis, organic carbon, protoplasm, mixed liquor suspended solids, and orthophosphates.

RATE OF PHOSPHORUS IN WASTE TREATMENT PROCESSES: ENHANCED REMOVAL OF PHOSPHATE BY ACTIVATED SLUDGE

California University, Richmond, Sanitary Engineering Research Lab.
A. B. Menar and D. Jenkins
Environmental Science and Technology, Vol. 4, No. 12, pages 1113–1121 (Dec. 1970)

Activated sludge must contain 2–3% phosphorus by weight in order to grow. Phosphorus removals in excess of this level are caused by chemical precipitation, with the phosphate being entrapped in the sludge floc and carried along with it. Precipitation is dependent on sewage pH, which is in turn dependent upon CO2 concentration. If at some point along the length of the aeration basin the DO and pH rise, then precipitation will occur with a resulting phosphorus removal. This phenomenon is not dependent upon the conventional operational parameters such as organic loading and mixed liquor suspended solids.

Keywords: phosphates, precipitation, carbon dioxide, hydrogen ion concentration, dissolved oxygen, chemical oxygen demand, organic loading, activated sludge, pilot plant, wastewater treatment, Texas, biological luxury uptake, calcium precipitation, calcium phosphate entrapment, carbon dioxide stripping, phosphorus assimilation, agglomeration, sludge volatility, and suspended solids.

PHOSPHATE REMOVAL

PHOSPHOROUS REMOVAL BY FERROUS IRON AND LIME

Rand Development Corp., Cleveland, Ohio
E. T. Alvord, D. M. Gaughan, C. M. Marr, T. Colpetzer, and D. B. Rose
Available from GPO Sup. of Doc. as EP2:10:11010 EGO—01/71, $0.75; microfiche from NTIS as PB-208 208, $0.95. Environmental Protection Agency Water Pollution Control Research Series, 71 pages (Jan. 1971)

Spent pickle liquor, a source of ferric ion, was added to primary treatment facilities and found to be effective in removing more than 60% of the phosphorus contained in the sewage. When advanced means for more complete removal of the insolubilized phosphates are available, removals in excess of 90% are indicated. In addition, overall suspended solids removals averaged 61.6 and 55.3% during a 23-month test period. Required iron dosage ranged from the theoretical minimum of 2.7 to a maximum of approximately 3.1 weights of ferrous iron per weight of phosphorus. The weight increase in sludge solids due to chemical precipitation of phosphorus was 100 lbs/million gallons/mg/liter of phosphorus in the influent. Enhanced suspended solids removals represented an additional 420 lbs/mg. Total costs for treating raw sewage containing 13 mg/l of phosphorus, as typically received during this work, were estimated at $14.17 per million gallons.

Keywords: municipal wastes, phosphorus, chemical precipitation, iron, lime, sludge, acids, separation techniques, cost analysis, flocculation, anaerobic digestion, wastewater treatment, waste pickle liquor, and suspended solids.

THE MECHANISM OF ACTIVATED SLUDGE PHOSPHATE RELEASE AND METHODS OF CONTROL

Reynolds Metals Co., Richmond, Va.
B. S. Hulcher, P. H. King, and C. W. Randall
Preprint, presented at Industrial Waste Conference, 26th, Lafayette, Indiana, 22 pages (May 4—6, 1971)

Samples of sludge produced from aeration of combined municipal and industrial wastes were obtained from a full-scale treatment plant and placed in laboratory scale units for testing. These units provided activated sludge treatment with settling and sludge recycle. Measured variables included pH, DO, COD, MLSS, orthophosphate concentration (PO4), aeration rate, and occasionally some others. Orthophosphate uptake was also monitored during most of the test runs. Results showed that phosphate release was closely related to suspended solids concentration in the mixed liquor and under anoxic conditions, the rate of aeration may also effect release. Activated sludge PO4 release is mainly biological in nature, and is a function of the stress placed on the microorganisms, whatever the cause. Cell lysis and dissolution is the principal mechanism involved, although viable cell leakage does occur. Optimum control methods involve stimulation of uptake to as great an extent as possible, coupled with the removal of the biological solids from the liquid as rapidly as possible, with some type of polymer usage making the suppression of release during separation more feasible.

Keywords: activated sludge, phosphorus, separation techniques, phosphates, nutrients, eutrophication, aeration, sedimentation, chemical precipitation, anaerobic conditions, dissolved oxygen, hydrogen ion concentration, microorganisms, metabolism, wastewater treatment, adsorption, lysis, dissolution, suspended solids, and orthophosphates.

PHOSPHORUS REMOVAL—THE STATE OF THE ART

Pennsylvania State University, University Park, Department of Civil Engineering
J. B. Nesbitt
Journal Water Pollution Control Federation, Vol. 41, No. 5, pages 701—713 (May 1969)

The occurrence of phosphorus in wastewaters must be controlled to prevent: 1) fluctuations in dissolved oxygen, 2) undesirable tastes and odors, 3) growth of undesirable plant life, and 4) increased organic loading on the receiving water because of plant decay. Phosphorus may occur in wastewaters in the form of organic, complex inorganic, and soluble inorganic phosphorus. Present methods of measuring phosphorus are inadequate. Removal practices that have been studied are biological methods (conventional activated sludge), chemical treatment (ion exchange and lime, alum, or iron precipitation), and chemical-biological treatment. An analysis of all applicable methods shows them to be feasible, but at a probable doubling of normal treatment plant costs [0.003 to $0.09/1000 gal (3785 1) for phosphate removal.]

Keywords: phosphorus, filtration, ion exchange, eutrophication, nutrients, wastewater treatment, biological treatment, sewage treatment, and chemical treatment.

PHOSPHORUS REMOVAL BY LUXURY UPTAKE

Greater Manassas Sanitary District, Prince William County, Va.
M. C. Mulbarger, M. C. Murphy, D. G. Shiflett, and D. D. Huffman
Journal Water Pollution Control Federation, Vol. 43, No. 8, pages 1617—1628 (Aug. 1971)

A 1.0 mgd wastewater treatment plant designed for biological phosphorus removal by luxury uptake within the activated sludge system was evaluated at a wide range of operating variables. Primary clarification was eliminated to provide greater solids levels for removing phosphorus, and dissolved air flotation was used in lieu of secondary settling to prevent the occurrence of anaerobic conditions and subsequent phosphate release. Anaerobic digestion of waste sludge released the phosphates in the elutriate, where they could be removed chemically if necessary. Enhanced phosphorus removals were demonstrated to occur through a combination of metabolic and physical-chemical mechanisms that are incompletely understood. The maximum phosphorus: COD removal ratio was 0.026 at a first-stage CRT of 3.6 days. Removals were not subject to precise controls, since the internal metabolic and/or chemical precipitation mechanisms were limited by the variability of the wastewater quality and the activated sludge system performance. Cost of the system was 2 to 3 times the cost of conventional activated sludge systems. Therefore, such designs should be avoided, and high-level phosphorus removals, if they occur in some installations, should be treated as a bonus.

OPERATION OF CONVENTIONAL ACTIVATED SLUDGE FOR MAXIMUM PHOSPHORUS REMOVAL

Weston (Roy F.), Inc., West Chester, Pa.
W. F. Milbury, D. McCauley, and C. H. Hawthorne

Journal Water Pollution Control Federation, Vol. 43, No. 7, pages 1890—1901 (July 1971)

The Baltimore, Maryland, Back River treatment plant was the site of intensive testing to determine optimum conditions for phosphorus removal through the activated sludge system. The 20-mgd conventional activated sludge system was subjected to variations in hydraulic and organic loading, temperature, sludge volume index, pH, nitrification, and primary effluent suspended solids, none of which seemed to affect phosphorus removal adversely. The following operational steps were demonstrated to be necessary in producing maximum phosphorus reductions: 1) phosphorus-rich wasted activated sludge must be handled carefully to prevent the recycle of phosphorus to the system, 2) the aeration tank must be operated in the plug flow mode, 3) aeration capacity must be maintained such that dissolved oxygen is not limiting (2.0 mg/l or more), 4) activated sludge must be wasted on a continuous basis to avoid abrupt sludge wasting, 5) the aeration tank must be operated at or above a suspended solids range of 1200 to 1300 mg/l, and 6) the secondary clarifiers must be operated such that the development of anaerobic conditions in the sludge blanket and secondary effluent solids are minimized. Operation under these restraints produced in excess of 80% phosphorus reduction over extended periods.

Keywords: phosphorus, activated sludge, water quality control, municipal wastes, Maryland, mixing, dissolved oxygen, temperature, hydrogen ion concentration, nitrification, organic loading, nutrients, wastewater treatment, suspended solids, Baltimore, and sludge volume index.

THE RELATION OF ORP TO ORTHOPHOSPHATE RELEASE BY ACTIVATED SLUDGE

Virginia Polytechnic Institute and State University, Blacksburg
D. W. Marshall

Master's Thesis, 91 pages (May 1968)

A series of seven experiments was performed to determine the factors associated with the secretion of phosphate back into solution by activated sludge under anaerobic conditions. Various concentrations of Na2SO4 and MgSO4 were added to the mixed liquor. Oxidation-reduction potential (ORP) was measured electrometrically be means of platinum and saturated calomel electrodes. It was thought that phosphate release occurred as a function of a drop in the ORP. Therefore, the addition of the sulfate containing chemically bound oxygen would raise the ORP and inhibit phosphate release. The factors that were closely monitored in an attempt to prove or disprove this theory were: 1) the extent of phosphate uptake and release with aeration, 2) the variation of the ORP, and 3) the corresponding phosphate release with and without the addition of sulfate salt. Results indicated that anoxic release of orthophosphate depended upon adverse cell metabolism factors causing lysis, not on variation of the ORP. While sulfate salts in a 1% solution or less had no effect upon orthophosphate release, a 2% solution of MgSO4 accomplished a 46% reduction, presumably by a reduction in cell lysis rather than ORP manipulation.

Keywords: oxidation-reduction potential, phosphates, solubility, anaerobic conditions, aeration, oxidation, dehydration, dissolved oxygen, activated sludge, metabolism, sulfates, electrodes, wastewater treatment, orthophosphates, nutrient removal, anoxic conditions, and lysis.

AUTOMATION AND CONTROL OF PHYSICAL–CHEMICAL TREATMENT FOR MUNICIPAL WASTEWATER

EPA, NERC, Advanced Waste Treatment Research Lab., Cincinnati, Ohio
J.J. Convery, J.F. Roesler, and R.H. Wise

Proceedings of International Conference on Water Pollution Research and American Institute of Chemical Engineers, Vanderbilt University (Sept. 18–22, 1972)

The Blue Plains pilot plant in Washington, D.C., is being used to evaluate the economic and technical feasibility of several automatic control strategies. The physical-chemical processes being evaluated at Blue Plains consist of two-stage lime precipitation, recarbonation, filtration, pH control with Cl_2, CO_2 stripping, breakpoint chlorination, and granular carbon adsorption. For lime ppt, four control strategies were evaluated for directing the addition of lime. Although feed-forward alkalinity mass-loading gave the smallest deviation from the desired target, it exhibited several solid handling problems; the investigators recommend a pH plus flow proportional control system, with conductivity ratio as a backup. Similarly, pH plus flow proportional control is recommended for CO_2 during recarbonation. Among the four control modes evaluated for the filtration processes and activated carbon adsorption (head loss, influent level, programmed interval, and manual), a programmed interval gave the best performance with the lowest operating cost. Economic breakpoint chlorination requires chlorine and pH control. The Cl_2 dosage control loop employs feed-forward influent ammonia mass-loading and feedback free residual chlorine; the control loop for alkali addition (NaOH) utilizes feed-forward chlorine dosage and a feedback pH error. In the near future, direct digital control will be evaluated in Blue Plains. In addition, the process computer will perform data acquisition and alert operators to alarm conditions. With respect to economic justification, based on 1971 cost data and a 10-mgd facility, four control schemes (dosing to meet peak daily requirements, periodic operator adjustments, flow proportional dosing, and mass proportional dosing) were evaluated for alum addition for phosphorus removal and methanol addition for denitrification. Based on equal effluent quality, mass-proportioned control can be economically justified.

Keywords: physical-chemical treatment, process control, instruments, automation, economic justification, and performance.

COMPUTER CONTROL OF PHYSICAL-CHEMICAL WASTEWATER TREATMENT

D. F. Bishop, W.W. Schuk, R.B. Samworth, R. Berstein, and E. Fein

Presented at 1st International Meeting of Society of Engineering Sciences, Tel Aviv, Israel (June 1972)

Advanced waste treatment systems in the EPA D. C. pilot plant include: 1) an analog-automated physical-chemical treatment system, applied directly to remove solids and phosphorus, 2) filtration to remove residual turbidity, 3) chlorination with pH control to remove ammonia, and 4) granular carbon adsorption to remove soluble organics. The pilot plant typically reduces the residual pollutants to 5 mg/l of BOD, 15 mg/l of COD, 0.15 mg/l of phosphorus, and 2.6 mg/l of total nitrogen. The control objective in the plant is to produce the best possible quality of wastewater effluent with minimum chemical usage. The controlled variables include flow rate, organic concentrations, alkalinity, pH, NH_3, PO_4, and residual-free chlorine concentrations. An IBM digital computer system (System/7) with flexible hardware and software was designed for the pilot plant. The process control computer also included a data acquisition and alarm monitoring function on other pilot systems by collecting plant data from approximately 80 wastewater process sensors. Control algorithms were developed from analyses of the plant characteristics, including the existing sensors and actuators. The IBM System/360 Continuous System Modeling Program was used to simulate the plant under digital computer control and provided predictive performance data, using the designed control algorithms on the simulated plant. The simulation analysis included a sensitivity analysis to determine controlled plant response characteristics under conditions of uncertainties or errors in knowledge of plant parameters. The existing analog-controlled plant was simulated to provide relative performance information and to verify the plant model. The control algorithms developed and verified in this work will be programmed, tested, and implemented on the actual pilot plant with an IBM System/7 computer.

Keywords: instrumentation, automatic control, DDC, algorithms, simulation, data acquisition, sensitivity, wastewater, and physical-chemical treatment.

REVERSE-OSMOSIS RENOVATION OF MUNICIPAL WASTE WATER

D.L. Feuerstein and T.A. Bursztynsky
Aerojet-General Corporation
U.S. Federal Water Quality Administration, Water Pollution Control Res. Ser. ORD-17040EFQ 12/69, U.S. Government Printing Office, Washington, D.C., 170 pages, $1.50 (1969)

Results are given of detailed laboratory experiments on the use of reverse osmosis to treat secondary sewage, carbon-treated secondary sewage, alum-treated secondary sewage, primary sewage, alum-treated primary sewage, crude sewage, and digestion supernatant liquor; in all cases significant improvements were obtained, with high removals of dissolved minerals, organic matter, and suspended solids. The effects of coagulants, dispersants, and chelating agents for maintaining a satisfactory product water flux were compared, and the best results were obtained with coagulants; the most satisfactory preliminary treatment of the sewage was found to be coagulation with alum, followed by rapid sand filtration. A computer model of the reverse-osmosis process was developed for rapid and accurate determination of the design and cost of reverse-osmosis facilities.

Keywords: reverse-osmosis, sewage, secondary sewage, coagulants, model, computer, design and cast.

REVERSE OSMOSIS PROCESS FOR WATER REFUSE APPLICATION

Office of Saline Water, Washington, D.C.
K.C. Channabasappa
Water-1969, Chemical Engineering Progress Symposium Series 97, Vol. 65, published by American Institute of Chemical Engineers, New York, pages 140—147 (1969)

Technical details of the reverse-osmosis waste water treatment process and an economic evaluation of its application to the treatment and reuse of secondary sewage effluents or industrial water wastes are presented. Under present conditions, costs range from 20 to 35 cents/1,000 gal; advances in reverse-osmosis membrane technology in the near future are expected to lower these costs further.

Keywords: water reuse, reverse osmosis, water costs, economics, reclaimed water, desalination, desalination processes, industrial wastes, industrial water and industrial water reuse.

REMOVAL OF ORGANIC REFRACTORIES BY REVERSE OSMOSIS

Washington State University, College of Engineering, Pullman
P.J. Bennett, S. Narayarian, and E. Hindin
Proceedings of the Industrial Waste Conference, 23rd pt, pages 1000—1017 (1968)

A laboratory-scale reverse osmosis unit was employed to determine the efficiency of modified cellulose acetate membranes to reject organic refractories. The unit was operated at 100 atmospheres and flux between 5 and 25 gallons/sq. ft./day with varying feed concentrations. Pure solutions of 19 different chemical species were examined as well as 7 different mixtures.

Rejections ranged between 14 and greater than 99.9%. In addition, several species were mixed with trickling filter and activated sludge effluents, resulting in reductions of between 21.4 and greater than 98% depending upon initial concentrations and operating conditions. Reverse osmosis is capable of producing a product water extremely low in organic matter excepting those organic compounds that have a vapor pressure higher than water when in solution or a dispersion.

Keywords: reverse osmosis, organic compounds, membranes, tertiary treatment, membrane processes, industrial wastes, effluents, efficiencies, and water reuse.

REVERSE OSMOSIS DEVELOPMENTS

Santa Rosa Medical Center, San Antonio, Texas, and Texas University, Austin
D.L. Goss and E.F. Gloyna
Water Quality Improvement by Physical and Chemical Processes, University of Texas Press, Austin, pages 312—326 (1970)

An historical development of the phenomenon of semi-permeable membranes and osmosis, beginning with Abbe Nollet's observations in 1748, is presented. Some of the advantageous features that reverse osmosis offers as a separation process include: 1) low energy requirements since phase changes are not required to effect the separation, 2) simple and flexible operation, and 3) compact plant size. The heart of the process is a semi-permeable membrane. Although improved membranes are being developed, the modified cellulose acetate membranes have been forerunners in the reverse osmosis process and have brought in-process to the point where it merits practical consideration in many water separation applications. A transport equation is developed, based on a Fickian diffusion process. The solute transport is accomplished by adsorption, diffusion, and the desorption process, with diffusion assumed the rate controlling step. Various operational considerations are presented. The physical and chemical degradations limit the useful lifetime of the present-day RO membranes to about from 6 to 12 months. Cost estimates for small brackish water reverse-osmosis plants are presented. For a MGD plant the total costs, including plant amortization, membrane replacement, energy, operation, and maintenance, are $0.59/1000 gallons. For the same conditions a 10 MGD plant is $0.38/1000 gallons.

Keywords: reverse osmosis, operations, membranes, membrane process, history, mathematical model, design, desalination, waste water treatment, tertiary treatment, systems, and transport equation.

PERFORMANCE OF POROUS CELLULOSE ACETATE MEMBRANES FOR THE REVERSE OSMOSIS TREATMENT OF HARD AND WASTE WATERS

Ottawa Pollution Control Center (Ontario), and National Research Council of Canada (Ottawa, Ontario), Division of Applied Chemistry
A.R. Jaicl and S. Sourirajan
Environ Sci and Technol, Vol. 3, No. 12, pages 1269—1275 (Dec. 1969)

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REVERSE OSMOSIS

The performance of a few typical Loeb-Sourirajan type porous cellulose acetate membranes is reported for the treatment of hard, polluted, and sewage waters. The membranes used are specified in terms of pure water permeability constant and solute transport parameter for sodium chloride. Using feed waters containing 300- to 800-ppm hardness, product waters containing 2 ppm or less could be obtained with 90% product recovery and an average initial flux of 38 gpd per sq. foot at 1000 psig. The possibility of producing 'ultrapure' waters by repeated reverse-osmosis processing is indicated.

Keywords: water treatment, desalination processes, water reuse, waste water treatment, reverse osmosis, demineralization, membranes, membrane processes, ions, solutes, industrial wastes, reclaimed water, alkylbenzene sulfonates, and deionization.

POLYMERS FOR SEWER FLOW CONTROL

Environmental Protection Agency, Washington, D. C. Storm and Combined Sewer Control Branch
G. A. Kirkpatrick
IN: Combined Sewer Overflow Seminar Papers, pages 37—51 (Mar 1970)

The reduction of pipe friction, with its corresponding increase in flow was the subject of a 29 month research and demonstration project. 6 polymers were tested as to their ability to decrease pipe friction. Of these, Polyox Coagulant-701 and WSR-301, both supplied by Union Carbide Co. and AP-30 supplied by Dow Chemical Co., were the most effective. Concentrations of 150-200 ppm of polymer caused flow increases of as much as 2.4 times the original flow. From laboratory testing, the project moved on to a 1563 ft. length 30 inches diameter sewer line in Dallas. 6 piezometers were positioned, and provisions were also made for temperature measurement and sewage sample collection. Four runs were made to test Polyox WSR-301 and Polyox Coagulant-701 with polymer concentrations varying from 35-100 mg/l. These and other laboratory studies have yielded the following results: (1) polymers are nontoxic to bacteria found in sewage during these tests; (2) polymers have neither toxic nor nutrient effects on algae; (3) polymers are not toxic to fish; (4) a 500 mg/l concentration of polymer has a BOD5 of 1.56 mg/l; and (5) polymers aid in the dewatering of sludge. Addition of polymers to sewer lines in Garland, Texas to relieve surcharging of the lines is estimated to cost $6400/year. Construction and operation of a relief sewer would cost $27,000/year. Because of the promise shown in the initial research, much polymer research is continuing.

Keywords: pipes, roughness (hydraulic), resistance, viscosity, friction, headloss, hydraulic gradient, turbulence, laminar flow, flow rates, pressure, temperature, slurries, biochemical oxygen demand, activated sludge, toxicity, dewatering, pumps, polymers, surcharging and damping.

DISPATCHING SYSTEM FOR CONTROL OF COMBINED SEWER LOSSES

Minneapolis-St. Paul, Sanitary District, Minneapolis, Minn.
J. J. Anderson
An Interim Report to the Federal Water Pollution Control Administration, Minneapolis-St. Paul Sanitary District, Minneapolis, Minn., pages 115 (May 1969)

The report describes a $1,741,000 demonstration project initiated as part of a national program designed to find alternatives to the costly method of sewer separation for reducing pollution of receiving waters from overflows of combined sewers. Key combined sewer regulators in the Minneapolis-St. Paul sewer system were modified. A system for remote control of these regulators and a system for monitoring liquid levels in major sewers are operational, using a small process control computer and leased telephone lines. Remote reading rain gages were connected to the system to permit using a mathematical model in the computer to predict storm flows in the interceptors and to guide operation of the regulators. To evaluate the effectiveness of these system modifications and the pollution caused by the sewer system existing District data was converted to data processing form, the hourly strengths of wastes in the system were determined and five robot monitors were installed to automatically record river water quality. The system, which is now operational is said to be the most advanced of any municipal system in the United States. Significant reductions of pollution of the Mississippi River from overflows are attributed to: manual-remote monitoring of sewer levels, regulator modifications, and improved regulator maintenance. The program has demonstrated that overflow regulators can be remotely controlled using a computer-based telemetry system. The original completion data of July 1, 1969 cannot be met because of delays caused by a flood and contract difficulties.

Keywords: flow control, gate control, control systems, computers, telemetry, automatic control, regulated flow, pollution abatement, remote sensing, remote control, data processing, maintenance, surface runoff, sewers, outlets, urbanization, monitoring, Mississippi River, Minnesota, computer control of combined sewers, combined sewers, overflow regulation and interceptors

COMBINED SEWER REGULATION AND MANAGEMENT

American Public Works Association, Chicago, Ill. Research Foundation
Available from NTIS as PB-195 676, $0.95 in microfiche. Also for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402. SOD 167.13/4: 11022D-MO 08/70. Water Control Research Series 11022 DMU 08/70, pages 134, (July 1970)

Design application, operation and maintenance of combined sewer overflow regulator facilities are detailed in this Manual of Practice, developed in conjunction with a report prepared on combined sewer overflow regulators, Design calculations are given for various types of regulators and tide gates. A sample regulator facility control program is given to illustrate the development of a control system. Operation and maintenance guidelines are also given. Thirty-eight sketches and photographs are included.

Keywords: overflow, regulation, design, operation, maintenance, sewers, water pollution control, waste water treatment, combined sewers, system control, quantity of overflow, tide gates and overflow regulation.

SANITARY SEWAGE TRANSPORT VELOCITY

American Society of Civil Engineers, Cambridge Mass.
M. B. McPherson, L. S. Tucher and M. F. Hobbs
Advances in Solid-Liquid Flow in Pipes and Its Application; Pergamon Press-Oxford and New York, pages 221—226 (1971)

Tests are summarized of the minimum required flow velocities of sanitary sewage in closed pressure conduits and open channels to preclude deposition of solids. Hydraulic experiments were conducted at the Central Engineering Laboratories of the FMC Corporation in Santa Clara, California using clear plastic pipe of different diameters, from 2 inches through 8 inches. Sewage analyses included, determination of pH, COD, grease, total solids, total volatile solids, suspendes solids, settleable solids, and specific gravity and amount of settleable solids on each of eleven sieve fractions, the last in terms of both suspended and volatile content. Because no meaningful correlation could be obtained between minimum transport velocities and sewage characteristics analyzed in the initial series of tests, sewage sand content was also determined in the final tests, including specific gravity and amount of each sand sieve fraction. Minimum sand transport velocity findings of Craven for closed conduits, and of Ambrose for closed conduits and open channel flow, are presented as correlated by

Laursen. All appropriate full conduit flow data from Ambrose and Craven and the sewage tests are summarized. Velocities causing deposition of suspended solids, and also scouring, were studied. Both comminuted and uncomminuted sewage was employed. This work was conducted in conjunction with the Combined Sewer Separation Project of the American Society of Civil Engineers. It is a study of pressurized sanitary sewerage systems wherin sewage would be pumped from buildings into pressure conduits in existing combined sewers.

Keywords: hydraulics, flow rates, sewers, settling velocity, pipe flow, pipelines, sewage disposal, flow separation, sediment transport, sanitary engineering, pressure conduits, open channel flow, design flow, laboratory tests, combined sewers, sanitary pressure sewers and sewer separation.

QUANTITY AND QUALITY RELATIONSHIPS FOR COMBINED SEWER OVERFLOWS

San Francisco, Calif., and Engineering-Science, Inc., Oakland, Calif.
A. O. Friedland, T. G. Shea and H. F. Ludgwig
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970) Preprint, Paper I-1

The results of a one year program of wet and dry weather monitoring of five combined sewer systems and one storm sewer system in San Francisco, is presented. The time concentration profiles of combined sewage constituents follow a definite three-phase variagion initially having characteristics of raw sewage increasing in the second phase to 125 to 200% of the characteristics of raw sewage, and receding in the third phase to levels of 10 to 25% of the characteristics of raw sewage. No correlation was found between the mass emission of constituents due to storm and the antecedent dry period, land use character, or rainfall intensity. Storm runoff emission equations for COD total suspended solids total nitrogen, orhto-phosphate phosphrous. Hexane extractable material and floatables can be used in conjunction with dry weather flow, waste load coefficient, a rainfall history, basin acreage and population to estimate waste water loads. Weather diversions contain twice the total nitrogen and ortho-phosphate phosphraous, 50 to 60% more total nitrogen and COD, 20% more floatables, and 10% more total suspended solids than the strom runoff fraction of the diversion alone would contain. The nitrogen and phosphrous emissions from secondary forms are significantly greater than emissions of these constitutes from combined or storm sewage flows on an annual basis.

Keywords: monitoring, flow, hydrology, mathematical, models, hydrograph, storm runoff, storage, waste water treatment, water pollution, water quality, and combined sewage.

POLLUTION CONTROL STARTS IN THE COLLECTION SYSTEM

Black and Veatch, Kansas City, Mo.
J. O. Schmidt
Preprint, presented at 44th annual conference of water pollution control federation, session 15, No. 3 (Oct 6, 1971)

The problem of excess extraneous water inflows into sanitary sewers during wet weather periods has existed, but has been tolerated and controlled by by-passing. However, increased wastewater flows together with increased downstream use have caused serious problems and by-passing untreated wastes from sanitary sewer systems is no longer acceptable. Three basic measures which can be taken to reduce the effect of extraneous water entering sanitary sewers are: (1) reduce extraneous water inflow to existing sewers, (2) prevent extraneous water entrance into new sewers, and (3) treat overflows, the first can be accomplished by flow monitoring, repair and replacement using improved methods and materials, and continuous inspection, particularly of house service connections. New and Improved construction material plus strict specifications and TV inspection of new sewer lines can reduce excess flows. Construction of storm water pollution control stations may be necessary to treat overflows that cannot be avoided.

Keywords: preprint, sewers, infiltration, drainage water, waste water treatment, maintanance, monitoring, specifications, construction materials and overflow, waste water bypassing, collection systems, and television inspection.

DISPATCHING SYSTEM FOR CONTROL OF COMBINED SEWER LOSSES

Minneapolis-St. Paul Sanitary District, Minn.
R. L. Callery

Copy available from GPO Sup Doc as SN 5501-0103, $1.75; Microfiche from NTLS as PB-203 678, $0.95. Environmental protection Agency, Water Quality Office, Water Pollution Control Research Series Report, pages 206 (March 1971)

Results of initial operation of a computer-based data acquisition and control system for a major urban combined sewer system are presented. Impressive reductions in combined sewer overflow pollution of the Mississippi River in Minneapolis and St. Paul have been effected. Working entirely within the limits of the existing interceptor sewer system, and with relatively minor modifications to selected major combined sewer regulators, incidence of overflow was reduced by 66% and duration of overflow by 88% during most of a rainfall season. Computer simulation techniques using actual rainfall data indicate that the amount of overflow volume reduction achieved is the equivalent of a $200 million separation project. The reduction in volume of combined overflow to the river is estimated to be between 35% and 70% during the runoff season. The combined sewer system captured about 77% of the urban runoff at the modified locations. A mathemetical model has been developed that will, with rain gage data as input, perform runoff analysis, diversion of combined sewer runoff hydrographs at regulators, and routing of diverted hydrographs through the interceptor system. Data from rain gages, regulator control devices, trunk sewers and interceptors, and river quality monitors provide real-time operating information. Time variant quality data from key locations in the sewer system have been acquired from analysis of numerous hourly samples.

Keywords: storm runoff, sewers, overflow, pollution abatement, mathematical models, diversion structures, routing, sewerage, sanitary engineering, water management (applied), simulation analysis, model studies, water pollution control, sampling, analysis, control, monitoring, combined sewers, regulator and urban hydrology.

MAXIMIZING STORAGE IN COMBINED SEWER SYSTEMS

C. T. Leiser
Seattle Metropolitan Municipality, Wash.

Copy available from GPO Sup Doc, $ 1.75; Microfiche from NTIS as PB-209 861, $0.95.
Environmental Protection Agency Water Pollution Control Research Series, pages 227
(Dec 1971)

A major portion of the Seattle Metropolitan area's comprehensive sewage collection and treatment plan launched in 1968, included improvements to an existing combined sewer system within Seattle's city limits. Initial plans included: (1) interception and treatment of raw sewage flowing to saltwater points, (2) regulation of combined flows to utilize all available trunk storage and (3) construction of temporary storage tanks at freshwater overflow points. In 1968, a $70 million sewer separation project was approved and will enlarge system storage by reducting storm inflow. All construction has been completed in an effort to demonstrate the feasibility of applying computer-control concepts to theoretically make maximum use of all available storage within a collection system. Automatic and manual sampling programs are monitoring overflows and adjacent waters. Accummulated and analyzed data shows dramatic improvements in receiving water quality resulting from interception and treatment phases of construction. Analysis of separation monitoring data projects a 50-70% reduction in pollutant loading to fresh water from combined sewer overflows. Overflow volume, frequency and quality factors are established to serve as a basis for measuring the performance of the control system as it leaves the instrumented local control phase and begins the totally computer-managed phase.

Keywords: waste storage, water pollution control, regulation, computer programs, overflow, infiltration flow separation, sampling, computer models, storm runoff, storage tanks, construction, telemetry, monitoring, calibrations, rainfall intensity, water pollution sources, water pollution effects, operations, maintenance, waste water treatment, waste water disposal, Washington, control systems and combined sewers.

THE EFFECTS OF OIL ON SEWERS AND TREATMENT PLANTS

Balfour (D.) and Sons, London (England)
J. R. Simpson

Water Pollution Control, Vol. 69, No. 5, pages 593—595 (1970)

Problems which can be caused by the presence of either extractable materials (EEM) must be recognized and compensated for in the design of sewage collection and treatment facilities. EEM is produced at the average rate CF 0.04 l/ capital/ day by the population of the United Kingdom. However, there is no typical condition governing EEM discharge into sewage systems since the amount of industrial oil introduced is variable. Design of treatment plants for prevention of EEM problems must involve careful consideration of: (1) pipe diameter and pump size; (2) the layout of pumps and pipe to facilitate cleaning and flushing; (3) the use of contruction materials which are readily cleaned when fouled; (4) chemical layout and accessability of the mechanical plant to facilitate cleaning; (5) provision of adequate skimming and scum removal devices; and (6) the type and layout of pump control systems to prevent fouling and facilitate cleaning. A need for the development of inexpensive, simple, reliable tests for differentiating free, immiscible, and emulsified EEM is also indicated as an aid in monitoring plant performance and in indicating which designs would be most effective.

Keywords: sewerage, waste water treatment, soil, scum, design criteria, pumping, pipes, activated sludge, sludge, metabolism, analytical techniques, treatment facilities, ether extractable material and grease.

CATAD SYSTEM CONTROLS FOR REGULATION OF COMBINED SEWAGE FLOWS

C. V. Bibbs, and S. M. Alexander
Water and Wastes Engineering, Vol. 6, No. 8, pages 66—69 (August 1969)

Combined sewers are designed to utilize the maximum storage during periods of high flow. A computer augmented treatment and disposal system (called CATAD) proposed for the municipality of Metropolitan Seattle is described. This program enables the minimization of the overflow of combined sewage. Existing local station controls and the principal objectives of the system controls are outlined. The paper also describes how the desired degree of control is achieved by the new system. Various components of the system and their primary functions are presented. A description of a mathematical model which will automatically control the system is presented. Apart from acting as a control for the combined sewage flow, the system also does recording and storing of water quality data for later analysis. The system has a good capability for future expansion.

Keywords: automatic control, telemetry, remote control, mathematical models, treatment plant, collection systems, interceptions, combined sewers, trunk sewer, outfalls, pumping stations, digital counter.

COMPUTER CONTROL OF COMBINED SEWERS

Minneapolis, St. Paul Sanitary District, Minneapolis, Minn.
J. J. Anderson
St. Paul, Minn; Watermation, Inc. (Oct 1969)

This paper describes a unique application of digital computers for maximizing the capture of urban runoff in the combined-sewer system of the Minneapolis-St. Paul Sanitary District. The real-time dynamic computer control of system overflow-regulators proved effective in helping to increase flows in interceptor sewers, thus reducing the frequency of overflows of raw sewage to the Mississippi River. Major overflow regulators were modified by replacing floats on the gates with hydraulic cylinders. Inflatable dams were installed trunk-sewer outlets. Level-sensing bubbler tubes with transducers and gate position slidewires were installed to provide sewer level and regulator-status information. Control and telemetry equipment were installed in underground vaults. The data acquisition and control system provides both manual-remote as well as automatic control of the system by central computer using leased telephone wires. The author describes the river monitoring and waste water sampling methods employed, the rain gage installations, mathematical modeling, and operating methods. He concludes that the feasibility of controlling and operating a large combined-sewer system, using centralized computer control, has been demonstrated and that this data acquisition system will facilitate future testing of improvements in water resource management.

Keywords: automatic control, gate control, computers, regulated flow, control systems, pollution abatement, surface runoff, remote processing, telemetry, dynamic programming, flow control, sewers, Minneapolis-St. Paul Sanitary District, combined sewers and overflow regulators.

SEWER MONITORING AND REMOTE CONTROL, DETROIT

Detroit Metro Water Service, Mich.
For sale by the superintendent of Documents, U. S. Government Printing Office, Wash. D. C. 20402-Price $2.50 In: Combined Sewer Overflow Abatement Technology, Water Pollution Control Research Series 11024 - 06/70, 219—290 (June 1970)

Detroit is faced with the problem of preventing pollution of the Detroit and Rouge Rivers from its combined sewer system overflows. As an alternative to undertaking a dubiously effective sewer separation program, estimated to cost in excess of two billion dollars, the Detroit Metro Water Department has installed the nucleus of a sewer monitoring and remote control 'system' for controlling the pollution from the combined flow from many small storms at a cost of slightly over two million dollars. The 'system' includes telemetering rain gages, sewer level sensors, overflow detectors, a centrally located computer and data-logger, and a centrally located operating console for controlling pumping stations and selected regulating gates. Installation has been virtually completed and now enables applying such pollution control techniques as 'storm flow anticipation','first flush interception', 'selective retention', and 'selective overflowing'. An evaluation of the effectiveness of this initial installation will serve as the basis for determining what additional pollution control facilities are required.

Keywords: storm drains, sewers, overflow, water pollution control, water quality, monitoring, remote control, rain gages, systems analysis, combined sewer overflows, storm flow anticipation, first flush interception, selective retentions, and selective overflowing.

STORM SEWER ASSESSMENTS

R. R. Daque
Public Works, Vol. 101, No. 8, pages 62—66, 118 (Aug 1970)

The author presents a method of storm sewer assessment which was applied to a project in Des Moines, Iowa. Four benefit factors considered in apportioning property costs can be utilized in storm sewer assessment if the relative weight of each fractor is determined by the relative benefit to be argued. Other factors to be considered reflecting costs and therefore benefit are: (1) the area drained (2) the runoff coefficient, (3) the rainfall intensity, (4) the distance to the outlet, (5) the unit pipe cost, and (6) the slope of the sewer. Each of these factors are discussed in relation to a sub-area. Once the dollar benefit to each sub-area is determined, the benefit to individual properties within sub-areas must be ascertained. Also, in arriving at storm sewer assessment, the benefit accruing to public property must be considered. Means for evaluating all of these factors are thoroughly described. The Des Moines procedure outlined in this article does not necessarily have application to all storm sewer special assessment problems. The test of the method will come through its application to a variety of storm sewer assessment problems along with success in the courts.

Keywords: cost-benefit analysis, assessments, runoff coefficient, rainfall intensity, drainage districts, costs and storm sewers.

COMBINED SEWER REGULATOR OVERFLOW FACILITIES

American Public Works Association, Chicago, Ill.
FWQA Contract No. 14-12-456. Program No. 11022DMU (July 1970)

Current design, operation, and maintenance practices used by local jurisdictions in the United States and Canada were determined by personal interviews and compiled in this report. Particular attention was given to the performance of various types of regulators, the use of tide gates, new designs, European practices, and the systems concept of combined sewer regulation. Thirty-seven drawings and photographs of regulators are included. 17 recommendations are made, the adoption of which would upgrade regulator facilities and tend to reduce receiving water pollution from combined sewer overflow.

Keywords: overflow, regulation, design, operations, maintenance, control systems, combined sewers, tide gates, overflow quantity and overflow quality.

CAN POLYMERS HELP YOUR COLLECTION SYSTEMS

J. W. Santry
Water Wastes Eng. Vol. 7, No. 11, pages 47—48 (Oct 1970)

The use of polymers, formed by chain grouping of similar organic molecules being cationic, anionic, or nonionic, reduce fluid flow friction resulting in an increased velocity in a sewer during application for varying distances downstream. What happens in the system is that the long chains of high molecular organic material dampen the eddy viscosity conditions making greater use of streamlining and the extension of the laminar boundary layer into the turbulent flow region. At present polymers appear to be limited to short time uses that occur because of peak flows and other emergencies.

NATIONAL 'RATIONAL' METHOD OF STORM DRAINAGE DESIGN (DISCUSSION)

R. A. Rogers
J Irrigation Drainage Div. Am Soc Civil Engrs. Vol. 96, No. IR3, pages 342—343 (Sept 1970)

The writer, discussing his original paper with the same title, has thus far been unable to comprehend, for the extreme case of a submerged storm system and assumed incompressible water, how the rate of flow out of the system at the outfall can differ from the rate of inflow at the inlets at any time. A lag time has been introduced into the computer program to allow for utilization of storage available within the system. The writer agrees with the thought that the design flows at individual points may be found from intensities occurring when peak flows reach the points, but he disagrees with the thought that the design for flows between the points can be made for the same hydraulic grade at different times.

Keywords: storm drains, flow rates, computer programs, methodology, drainage systems and design.

SOLUTION FOR STORM SEWER SYSTEM PROBLEM

L. E. McMahon
Am Assn State Highway Officials-Committee on Electronics-Regional Conf on Improved Highway Eng Productivity, Chicago, Ill., pages VII-14—25 (April 19-20, 1963)

Program was developed at Michigan State Highway Dept for solution of storm sewer system problem created by accelerated highway program; program is written for processing on 20K IBM 1620 computer equipped with floating point and indirect addressing features; solution is based on use of 'Rational Method for Design of Storm Sewer Systems' Manning formula and use of rainfall intensity and runoff curves developed to meet Michigan's needs.

Keywords: computer programs, design, rainfall intensity, rainfall-runoff relationships and storm sewers.

COMBINED SEWER REGULATION WITH FLUIDIC REGULATORS

P. A. Freeman
J. Wat. Pollut. Control Fed., 43, pages 862—87 (1971)

Studies have been carried out on the use of a fluidic regulator for controlling overflows from combined sewers; it is based on an automatic system developed for controlling irrigation in which flows are sequentially switched from a supply ditch into growing areas by means of large fluidic bistable elements that are controlled by the relative amount of ambient air flow aspirated into the control parts by the venturi-shaped flow entry nozzle. In adapting this system to regulation of combined sewer flows, the fluidic element is 'buried' in the dam of a typical static diversion structure, with one outlet of the element discharging into the intercepting sewer while the other discharges into an outfall; the regulator discharges all the flow into the interceptor until the level of sewage reaches a predetermined level at which a sensor is set, and then diverts the flow to the outfall. This system will be tested in Philadelphia, Penn., and Akron, Ohio.

Keywords: fluidic, regulators, flow, combined sewers and nozzle.

EFFECT OF STORM WATER ON THE SEWERAGE SYSTEM AND THE RECEIVING STREAMS

F. Popel
Kommunalwirtschaft, Vol. 9, pages 340 (1957)

The author discusses, with special reference to planning of new towns, the effect on streams of storm water overflows in combined sewerage systems. Calculation of the permissible amount must be based on the annual amount of discharge and of polluting matter in it, the self-purifying capacity of the stream, and the use made of the stream water. Investigations are required into the condition of the storm water in the modern conditions of traffic and efforts should be made to develop a reliable method of assessing the self-purifying power of a stream receiving sudden discharges of polluting matter.

Keywords: a storm runoff, planning, overflow, water pollution, urban drainage and combined sewers.

MICROSTRAINING

SCREENING AND MICROSTRAINING

TERTIARY TREATMENT BY MICROSTRAINING

Cochrane Products Crane Co., King of Prussia, Pa.
E.W.J. Diaper
Water and Sewage Works, Vol. 116, No. 6, pages 202–207 (June 1969)

A woven stainless steel cloth placed around the periphery of a partially submerged drum is used to strain the effluent of waste treatment plants. The drum rotates at a variable speed, and the collected mat is backwashed from the top of the drum into a collector. The cloth is available with openings of 60, 35, and 23 microns, but it removes much smaller particles because of the matting. A number of installations are described. The article gives available sizes (to 10 mgd) and costs (installed cost of $24,000 to $45,000 per mgd and operating costs of $2.50 to $4.00 per mg) for microstrainers.

Keywords: tertiary treatment, design data, costs, filter, stainless steel, microstraining, backwash, filter cloth, and filter runs.

MICROSTRAINING AND OZONIZATION OF WATER AND WASTE WATER

P.L. Boucher
Proceedings, 22nd Industrial Waste Conference, Purdue University, Engng Extn Ser. No. 129, pages 771–787 (1967)

After reviewing the processes involved in microstraining and ozonation and their usual applications in the treatment of water and sewage, the author outlines recent developments in the combined use of these processes, including the preliminary results of pilot-plant experiments on their use for treatment of secondary sewage effluent at the Redbridge sewage works (London). Some costs of the combined treatment are estimated.

Keywords: microstraining, ozonization, sewage, and pilot plant.

A DYNAMIC MODEL OF THE ANAEROBIC DIGESTION PROCESS

Clemson Univ., S.C. Dept. of Environmental Systems Engineering
J.F. Andrews
Proceedings of the Industrial Waste Conference, 23rd, pages 285—310 (1969)

Process stability has been the major problem associated with the anaerobic digestion process. A dynamic model which utilizes an inhibition function to predict the failure of an anaerobic digester was presented. The key features of the model were: (1) the use of an inhibition function to relate volatile acid concentration and specific growth rate for the methane bacteria; and (2) consideration of the un-ionized acid as the growth-limiting substrate and inhibiting agent. The consideration of the un-ionized acid as the inhibiting agent resolves the conflict between volatile acid inhibition and pH inhibition because the concentration of un-ionized acid is a function of both total volatile acid concentration and pH. The model was kept as simple as possible by assuming that there was no lag phase, organism death, endogenous respiration, substrate utilization for maintenance energy, or inhibition byproducts. Experimental evidence from laboratory studies and evidence from the bacteriological literature were presented in support of the model. Simulation studies, utilizing a digital-analog simulation program (PACTOLUS), of both batch and continuous flow systems provided additional evidence by predicting results commonly observed in the field during the start-up, or failure, or recovery of anaerobic digesters. The simulation studies should be considered as only semiquantitative as reliable values of the growth parameters were not available.

Keywords: anaerobic digestion, simulation analysis, inhibition, hydrogen ion concentration, mathematical model, anaerobic bacteria, laboratory tests, waste water treatment, volatile acid concentration and process stability.

NEW DEVELOPMENTS IN ANAEROBIC DIGESTION OF SLUDGES

Texas Univ., Austin
J.F. Malina, Jr. and E.M. Miholits
Advances in Water Quality Improvement (Editors: E.F. Gloyna and W.W. Eckenfelder, Jr.), Austin, Texas, Univ. of Texas Press, pages 355—379 (1968)

Primary and biological sludge treatment and disposal generated from waste water treatment present more difficult problems than liquid waste treatment alone. The complexity of biochemical reactions involved in the liquefaction and gasification of waste water sludges indicates vital need for external and internal control of the reaction variables. Optimum digestion requires solids mixing in a digestion tank by mechanical or gas recirculation methods, within the temperature range of 30 deg—35 deg C. The recommended volatile solids loading is 200 lb/1,000 cu. ft/day, with a detention time of from 10 to 15 days. Digester performance will be improved by maintaining the solids loading and hydraulic displacement as uniform as possible. The various chemical parameters characterizing the digester environment are sensitively interrelated. Therefore, for efficient digestion operations it is essential to determine and evaluate carefully the daily laboratory analyses of volatile acids, the alkalinity, the digestion sludge gases, pH, carbon dioxide production and other critical parameters of the particular wastes being treated.

Keywords: anaerobic conditions, digestion, sludge treatment, sludge disposal, sludges, chemical properties, solids contact processes, chemical degradation, organic compounds, temperature, mixing, digestion tanks, design criteria, alkalinity, biochemical reactions, anaerobic sludge digestion, high-rate digestion, Carter-Perth gas recirculation systems, 'Shearfusers' gaslifter digestion system, 'bubble guns' 'dynomix' system, 'densludge' system and 'aerohydraulic' system.

ANAEROBIC DIGESTION OF THICKENED SLUDGE

Mississippi State Univ., State College, Dept. of Sanitary Engineering
A. Shindala and T. G. Byrne
Public Works, Vol. 101, No. 2, pages 73—76 (February 1970)

As much as 30 to 50 percent of the total operating cost of a sewage treatment plant is utilized in sludge digestion. Laboratory experiments have been conducted to determine if anaerobic sludge digestion can be improved by operating the digesters at thermophilic temperatures. One gallon wide mouth jars were used as digesters. Seed sludge was taken from a primary digester at a local sewage treatment plant and raw sludge was taken from the underflow from the primary sedimentation basin of the same plant. Sludge was thickened to 15% solids in a low speed centrifuge. The digesters were operated at temperatures of 105, 120, 130 and 140 degrees F. It was found that increasing the digestion temperature from 95 to 105 degrees F increased gas production and that beyond 105 degrees deterioration in sludge digestibility occurred. Alkalinity and volatile acid concentrations increased as digestion temperatures increased. It is postulated that gas yields per unit of volatile matter from thickened sludges may still be adequate due to decreased heat requirements. The volume of gas produced should be judged in the light of the destruction of volatile matter, heat requirements and quality of gas produced.

Keywords: anaerobic digestion, waste water treatment, sludge digestion, anaerobic conditions, temperature, heat, economic analysis, laboratory tests, alkalinity, hydrogeon ion concentration, mesophilic, thermophilic, volatile acids, gas production and volatile solids destruction.

ANAEROBIC DIGESTION: I. THE MICROBIOLOGY OF ANAEROBIC DIGESTION

National Inst. for Water Research, Pretoria (South Africa)
D. F. Toerien and W. H. J. Hattingh
Water Research (J Int Assn of Wat Poll Res), Vol. 3, No. 6, pages 385—416 (June 1969)

Anaerobic digestion is defined as a biological process which converts organic matter to methane and carbon dioxide in the absence of oxygen. Anaerobic digestion is considered as a two-step process, acid formation (liquefaction) and gas formation (gasification). Two large, different bacterial populations must be present to reach the end point—the first group converts proteins, carbohydrates, and lipids into fatty acids by hydrolysis and fermentation and the second group converts the fatty acids into methane and carbon dioxide. Article is a review of research done on these two stages of anaerobic degradation with emphasis on bacterial populations and their nutritional and oxygen requirements. The metabolic and catabolic products along with the pathways of formation are delineated as far as is known.

Keywords: anaerobic, digestion, hydrolysis, review methane, carbon dioxide, microbiology, metabolism, respiration, fermentation, liquefaction, gasification, methanogenic bacteria, fatty acids, pathways, nutrition and bacterial population.

APPLICATION OF DIGESTION THEORY TO DIGESTER CONTROL

Iowa Univ., Iowa City
R. R. Dague
Journal Water Pollution Control Federation, Vol. 40, No. 12, pages 2021—2032 (Dec. 1968)

The successful operation of anaerobic digestion systems depends on the control of bacteria, food, contact time, temperature, pH, and toxic materials. Stabilization of raw sludge depends on the production of methane gas through an assembly-line-like process involving acid forming and methane forming bacteria. The methane producing assembly line can be operated at peak efficiency and stability by: (1) controlling the bacterial population which here refers to methane formers, (2) providing for uniform feeding with respect to both time and consistency, (3) adequate contact time determined through the solids retention time (SRT) not simply the hydraulic retention time, (4) uniform temperature which should be provided through adequate mixing and maintained at approximately 95 degree F, (5) suitable pH not dropping below pH of 6.5, and (6) eliminating excessive concentrations of toxic materials. This paper presents a discussion of the basic requirements and indices of digestion and the manner in which the basic requirements should be applied to digester control.

ELECTRODE POTENTIALS AND ELECTROLYTIC CONTROL IN THE ANAEROBIC DIGESTION PROCESS

Northeastern Univ., Boston, Mass.
F.C. Blanc and A.H. Molof
Proceedings, Industrial Waste Conference, 24th, pages 1040—1059 (May 6, 7, and 8, 1969)

With improved treatment methods and greater organic removals in the sewage treatment process, the problems of sludge stabilization and disposal have greatly increased. Anaerobic digestion is an extensively used method of sludge stabilization. Maximum efficiency is not being realized due to a lack of understanding of the process mechanism and control. The electrode potential measurement is a monitoring parameter that can be used effectively in the anaerobic digestion process. The potential was measured in laboratory experiments between a platinum indicating electrode and a calomel reference electrode. The potential measured was the sum of all the oxidation-reduction reactions taking place in the digester. Such potentials are apparently the result of the activity of the methane forming bacteria. These experiments indicated that optimum digestion took place at -510 MV EC with an operating range of -450 to -550 MV EC. Direct current electrolysis was demonstrated as a means of controlling the pH of the digester. This method was used to correct a depression in pH until the digester could recover and allowed the operation to continue at high concentrations of volatile acids and shorter detention times. The monitoring equipment can be installed for a modest capital cost. Electrolytic control of the pH appears to be feasible and should be tested further in pilot scale units.

Keywords: waste water treatment, anaerobic digestion, sludge digestion, methane bacteria, acid bacteria, electrolysis, hydrogen ion concentration, electrodes, automatic control, pH control and electrolytic control.

CONTROL OF ANAEROBIC DIGESTION PROCESS AND SUPPORTING UNIT PROCESSES

C. F. Guarino
Water Research, Vol. 6, page 503 (1972)

The city of Philadelphia plans to automate raw sludge pumping, sludge heating and anerobic digestion via a telephone telemetry communication with a private process control computer. Sludge density, measured by radioactive type density gauges, controls raw sludge pumping and activates sludge collectors. If the sludge is too thick, dilution water will thin it. Based on records back to 1951, CO_2 measurements on the digester gas are essential for digester control. The digest control strategy follows: 1) Provided adequate space exists, charge raw sludge directly to the digester with the most favorable CO_2 level and gas rate; 2) During charging or shortly thereafter mix digester via gas recirculation; 3) If temperature of charged digester is low, the digester will be recirculated through sludge heaters; 4) After temperature correction, allow sufficient settling time before supernatant or bottom sludge is withdrawn. Laboratory test such as pH, volatite acids, and alkalinity, manually inserted into the control program, establish secondarily the charging priority.

Keywords: sludge digestion, automation, process control, pumping, heating, gas, production and control strategy.

TOXIC EFFECTS OF AMMONIA NITROGEN IN HIGH-RATE DIGESTION

New York City Environmental Protection Administration, Dept. of Water Resources
N. R. Melbinger and J. Donnellon
Journal Water Pollution Control Federation, Vol. 43, No. 8, pages 1658—1668 (August 1971)

Although previous investigators had established 1700 to 1800 mg/l as the toxicity threshold for ammonia nitrogen in digesters, operating experience had revealed several instances of digesters operating in excess of these levels in various New York City Wastewater Treatment Plants. A series of digester failures starting in 1967 caused renewed interest in investigating the actual mechanisms. Monitoring of the digesters revealed that the ammonia nitrogen becomes toxic in a digester only when the rate of its formation above a 1700 to 1800 mg/l threshold limit is increasing more rapidly than the acclimation of methane-forming organisms. Control of the rate is possible by proper digester feeding, using the volatile acid: alkalinity ratio as a parameter, and ammonia nitrogen concentrations of 2700 mg/l have existed in acclimated digesters with no loss of efficiency. Controlled recirculation of digested sludge to the thickener has been used to control the ammonia nitrogen concentrations also. Finally, a definite relationship exists between the sludge ammonia nitrogen content and the digested sludge volatile solids and alkalinity.

Keywords: digestion, ammonia, toxicity, inhibition, sludge, on-site investigations, alkalinity, nitrogen, acclimatization, methane, bacteria, waste water treatment, digester failure, recirculation and ammonia nitrogen.

DISCUSSION OF 'TOXIC EFFECTS OF AMMONIA NITROGEN IN HIGH RATE DIGESTION'

Bergen County Sewer Authority, Little Ferry, N.J.
H.R. Zablatzky
Journal Water Pollution Control Federation, Vol. 43, No. 8, pages 1668—1670 (August 1971)

Results of the work performed by Melbinger and Donnellon indicate that possibly many of the old toxicity levels should be re-evaluated to consider possible acclimation effects. However, two requirements specified by them may limit the number of plants to which their own investigations may be directly applied. The plants would require some form of the activated sludge process, and undigested sludge thickening before digestion. In addition plant location and method of solids disposal can alter the degree of anaerobic treatment desired, affecting the quantity and quality of the intermediate and end products. The effects of these intermediate and end products on the process must also be considered. In addition, there may be a ratio of ammonia nitrogen to alkalinity that may depend on specific types and concentrations of sludges and allow the alkalinity to be used as an easy reference point for the inhibiting level of ammonia nitrogen.

Keywords: anaerobic digestion, ammonia, acclimatization, toxicity, inhibition, acids, alkalinity, methane, sludge, foaming, odors, waste water treatment and solids disposal.

ANAEROBIC DIGESTION II. THE CHARACTERIZATION AND CONTROL OF ANAEROBIC DIGESTION

National Institute for Water Research, Pretoria (South Africa)
J.P. Kotze, P.G. Thiel and W.H.J. Hattingh
Water Research, Vol. 3, pages 459—494 (1969)

Although well-operating digesters will always have a common feature in that organic material is eventually converted to methane and carbon dioxide, their bacterial populations, the sequence of reactions giving rise to end products, and the prevailing environmental conditions may differ widely. Digester character is dependent upon substrate composition and the number of species of microorganisms present in the inoculum, as well as temperature, loading rate, hydraulic residence time, sludge retention time, method of mixing sludge in the digester and the design of the container of the process. An extensive literature search resulted in a summary and description of digester characterization factors, and revealed that substrate composition and feeding rate were of greater influence than temperature, original inoculum, and mode of operation. Reference was made to such generally accepted ways of characterizing a digester as pH, volatile fatty acid concentration, alkalinity, gas production rate and composition, etc., with the realization that these parameters do not account for the intrinsic biological nature of the process bacteria. The analysis also revealed the paucity of knowledge of the biochemistry of the anaerobic digestion process, and the obvious priority that such knowledge must take in attempting to provide efficient and reliable characterization and control of an essentially biological process.

Keywords: anaerobic digestion, kinetics, biochemistry, fermentation, energy conversion, methane, bacteria, hydrogen ion concentration, alkalinity, sludge, metabolism, protein, nutrients, organic loading, waste water treatment, reviews, process characterization, process control and substrates.

INFLUENCE OF TEMPERATURE ON ANAEROBIC DIGESTION

Central Sewage Treatment Plant, Brno (Czechoslavakia)
J. Maly and H. Fadrus

Journal Water Pollution Control Federation, Vol. 43, No. 4, pages 641—650 (April 1971)

The relationship between the rate and degree of organic matter digestion in sludge and the temperature at which methane fermentation takes place was investigated both through the literature and in a series of laboratory tests. Sludge gas production and organic matter removals were determined for batch fermentation units at 20 deg C, 30 deg C, and 50 deg C. Increased temperature resulted in an increased rate of bacterial decomposition, but the resulting effect and final state of the process, as determined from removals of organic matter, organic carbon, and methane and CO2 production, were nearly identical for the different temperatures, provided sufficiently long fermentation periods were utilized. At higher sludge fermentation temperatures more ammonia would be evolved, due to failure of methane fermentation rate to increase with temperature. This ammonia evoluation from the high-molecular-weight nitrogenous compounds and their decomposition products would not always be accompanied by total mineralization.

Keywords: anaerobic digestion, fermentation, temperature, sludge, kinetics, bacteria, carbon dioxide, methane, ammonia, proteins, waste water treatment and reaction rate.

ANAEROBIC SLUDGE DIGESTION, MESOPHILIC-THERMOPHILIC

Western Kentucky Univ., Bowling Green
D.R. Rowe

Water and Sewage Works, Vol. 118, No. 3, pages 74—76 (March 1971)

Four laboratory scale anaerobic digesters were operated for a 4 week period. Two digesters were operated in thermosophilic range (35C), and two were operated in the thermophilic range (55C) to determine the temperature effects. The progress of digestion was evaluated by the volume of gas produced and by the decrease in volatile solids and the increase in fixed solids. pH, total solids, volatile solids, nitrate, nitrite, ammonia, alkalinity, and volatile acid analyses were performed on the sludge samples, and all determinations were made in accordance with Standard Methods. Overall results showed a higher rate of digestion taking place in the thermophilic digesters. Also, the thermophilic organisms were shown to be more efficient in the removal of nitrate and nitrite nitrogen. The increased efficiency of thermophilic digestion proved that satisfactory results could possibly be obtained in 7—15 days instead of the usual 24—26 days presently used in mesophilic digestion. Therefore, heating of the digesters to the thermophilic range could effectively double the digester capacity of an existing plant without additional construction.

Keywords: anaerobic digestion, temperature, methane bacteria, microorganisms, sludge digestion, alkalinity, hydrogen ion concentration, acidity, nitrates, nitrites, ammonia, methane, waste water treatment, volatile solids and volatile acids.

ANAEROBIC DIGESTION OF THICKENED SLUDGE AT VARYING TEMPERATURES

Mississippi State Univ., State College, Dept. of Civil Engineering
T.G. Byrne
Master's Thesis, 105 pages (August 1969)

Anaerobic digestion of activated sludge is one of the most complex methods of sewage treatment, as well as one of the most expensive. Many factors affect the digestion process: balance between methane formers and the acid formers, range of volatile acid concentrations, alkalinity concentration, sludge detention time, mixing method used, total solids content, loading rates, viscosity, and water content. In view of a recent finding that acceptable volatile solids reduction is possible from concentrated sludges, a need was seen to ascertain the effects of temperature on activated sludge. The study was done in two phases. During the first phase, a sludge of 15 percent total solids was digested at temperature of 105 deg F, 120 deg F, 130 deg F, and 140 deg F. Sludges of 5, 10, and 15 percent total solids were digested at 130 deg F during the second phase. Factors upon which the judging of the progress of digestion for the various sludges were based on total solids, volatile solids, pH, alkalinity, and volatile acids. Results of the study showed that temperature does have definite effects on the digestion of a thickened sludge. During this study, digestors operating at temperatures greater than 105 deg F showed distinct signs of impaired digestion as evidenced by high concentrations of alkalinity and volatile acids and extremely low production of gas.

Keywords: anaerobic digestion, activated sludge, sewage treatment, volatility, temperature, alkalinity, acidity, acids, methane, sedimentation, hydrogen ion concentration, waste water treatment, sludge treatment, volatile acids, acid formers, methane formers, sludge detention time and total solids content.

INCREASED LOADINGS ON DIGESTERS WITH RECYCLE OF DIGESTED SOLIDS

Illinois Univ., Urbana
J. T. Pfeffer
Journal Water Pollution Control Federation, Vol. 40, No. 11, Part 1, pages 1920—1933 (Nov. 1968)

Recycle of digested solids from the secondary digester back to the primary digester offers a means of increasing the loading rates with a dilute feed sludge while maintaining the solids retention time (SRT) necessary for stabilization. The increase in SRT associated with recycle produces an increase in total gas production, and a more stable digestion system. Controlling factors are the concentration of solids in return cycle sludge and the ratio of the desired solids retention time to the liquid retention time. A specific example is cited in which the recycle of digested sludge increased the volatile solids destruction from an average of 44,000 lbs/day to 53,000 lbs/day. The additional solids destruction also was reflected in the reduction of the volatile content of the digested sludge from 59.4% to 53.5% during recycling. Methane fermentation of the volatile acids has been found to be the rate limiting step in high rate digestion for 10—15 day systems, acid fermentation after 15 days.

Keywords: anaerobic digestion, operation, digestion, waste water treatment, methane bacteria, solids retention time, loading rate, recycle, volatile solids and acid fermentation.

SLUDGE STABILIZATION AND DEWATERING

A MATHEMATICAL MODEL FOR THE WET-AIR OXIDATION OF SLUDGE

Kyoto Univ. (Japan), Faculty of Engineering
T. Takamatsu, I. Hasimoto, and S. Sioya

Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970), Preprint, Paper II-32, 8 pages (July—August 1970)

It has been discovered that the wet-air oxidation of sludge is composed of two phenomena, that is, sludge decomposition without oxygen followed by the oxidation of the decomposed sludge by oxygen, at a temperature of 170—250 deg C and a pressure of 60—130 kg/sq cm-gauge. A mathematical model of this reaction process is proposed in terms of COD and weight of solid matter, soluble nonevaporative matter and soluble evaporative matter in sludge. The parameters involved in the mathematical model are estimated by a nonlinear estimation technique. Sludge is a highly complex mixture and the complexity of its composition makes it difficult to represent its thermal decomposition and oxidation in a mathematical form. As the mathematical model should be as simple as possible, the sludge content is roughly classified into four categories. They are: (1) solid matter, (2) soluble nonevaporative matter below 120 deg C, (3) soluble evaporative matter above 120 deg C, (4) pure water. Separate mathematical models are derived for the (1) thermal decomposition process, (2) relation between thermal decomposition and oxidation, (3) oxidation process. Experiments carried out by using artificially cultured activated sludge have verified that the model is applicable for the reaction of sewage sludge. Thus, it will become possible to control and design the wet-air oxidation process on a quantitative basis by using the mathematical model proposed here.

Keywords: mathematical models, oxidation, sludge, sludge treatment, chemical oxygen demand, sewage treatment, waste water treatment and decomposition.

AEROBIC SLUDGE STABILIZATION IN SEWAGE TREATMENT PLANTS

Technische Hochschule, Hanover (West Germany)
D. Kehr

Proceedings of the Third Internation Conference, Munich, Germany, pages 143—152 (1966)

Aerobic sludge stabilization and its economic and technical aspects have been investigated as a substitute for the use of large digesters employed in the anaerobic digestion process. The general design basis of design of an aerobic stabilization tank is .01 cubic meters/capita, or approximately 30% of the volume of a digester designed for the same load. On the other hand, aerobic stabilization requires energy in the form of pumping and compressors required to put oxygen into the system, whereas anaerobic digestion produces usable energy. Therefore a cost comparison of the two methods should be made in every case in order to determine which is less expensive. Sewage treatment plants serving 10,000 people or less are in many instances already employing joint activated sludge waste treatment and sludge stabilization.

Keywords: biodegradation, digestion, organic loading, microorganisms, nitrogen, phosphorous, biochemical oxygen demand, industrial wastes, municipal wastes, sludge, sewage treatment, waste water treatment, aerobic sludge stabilization, technical digestion limit, stabilized sludge, sludge age and sludge load.

DISCUSSION OF 'AEROBIC SLUDGE STABILIZATION IN SEWAGE TREATMENT PLANTS'

Vysoka Skola Chemicko-Technologicka, Prague (Czechoslovakia)
J. Chudoba

Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 153—157 (1966)

Two methods of aerobic sludge stabilization are presently employed in practice. Extended aeration has long been practiced, and for it to operate optimally, the following guidelines must be followed. Detention time in the aeration tank must be 24 hours, followed by 4—6 hour sedimentation time, while the organic loading must be from 240—320 g BOD5/day/cubic meter and the sludge loading cannot exceed .1 g BOD5/day/g Vss. Problems which occur are mainly due to poor sludge settleability, causing much of the organic material to pass through the outlet in the form of suspended solids. Formulae have been developed to determine the amount of non-degradable material which will remain, and the amount of degradable material which will be oxidized. The second method consists of separate aeration of sludges under continuous or discontinuous conditions. For this type of treatment, the aeration period is a function of certain sludge characteristics, notably the volatile suspended solids content. Experiments showed that higher volatile solids removals were effected at the lower loading rates. Temperature is also a significant factor. The higher the loading rate, the less the sludge will settle, and this usually requires installation of some additional sludge handling device, or separate sludge aeration tank.

Keywords: digestion, synthesis, kinetics, stabilization, organic loading, biodegradation, chemical oxygen demand, biochemical oxygen demand, activated sludge, water purification, sewage, aeration, waste water treatment, endogenous metabolism, sludge yield coefficient, sludge age, extended aeration, volatile suspended solids and mixed liquor suspended solids.

FACTORS AFFECTING pH IN ALKALINE WASTE WATER TREATMENT: II. CARBON DIOXIDE PRODUCTION

Technische Hogeschool Twente, Enschede (Netherlands)
L. Lijklema

Water Research 5(4): pages 123—142 (1971)

The CO2 produced during biological oxidation of wastewater has a pronounced influence upon the pH that is attained in the activated sludge process. The quantity produced is proportional to the COD (chemical O2 demand) removed, its degree of oxidation and the oxidation level of the substrate. A discussion of metabolism is given with emphasis on the O2 consumption. A mass balance for the metabolism of model compounds is presented. This model is based on a thermodynamic consideration of the metabolic process and offers a basis for calculation of RQ values. Experimental evidence for the applicability of this model is presented. Experimental results for a sewage are applied in pH calculations.

Keywords: activated, alkaline, carbon, di, dynamics, metabolism, oxide, pH, production, quotient, respiratory, sludge, thermo, treatment and waste water.

KINETICS OF WASTE ASSIMILATION IN ANAEROBIC TREATMENT

P. L. McCarty
Devs ind. Microbiol., 7, pages 144–155, 1965 (1966)

The kinetic theory of growth in pure cultures is outlined in relation to anaerobic treatment processes. When applied to the anaerobic degradation of complex organic waste waters from industry the kinetics of the rate-limiting step, which has been shown to be the production of methane from fatty-acids decomposition, are evaluated to determine the minimal solids-retention period desirable in relation to operating temperature as a basis for treatment plant design (see also Wat. Pollut. Abstr., 1968, 41, Abstr. No. 845). The possibility that the waste waters lack trace elements essential for the optimal growth of methane-producing bacteria should be considered.

Keywords: kinetics, rate-limiting, methane, retention time and anaerobic.

SPECIFIC GAS YIELD ATTAINABLE DURING ANAEROBIC DECOMPOSITION OF ORGANIC MATERIAL DEPENDING ON THE LOADING CONDITION

O. Tabasaran
Gesundheitsingenieur, 91, pages 327–329 (1970) (in German)

Specific quantities of gas yielded during anaerobic decomposition of organic substrates can be directly related to the content of organic carbon and the proportion of carbon substrates decomposed during prolonged reaction periods depends also on the ratio of bacteria to the substrates. The actual rate of decomposition cannot always be deduced from the amount of gas produced. With very low loads the synthesis of cell substance constitutes a higher percentage of the metabolism than does the dissimilation.

Keywords: anaerobic digestion, gas, methane, loads and cell synthesis.

USE OF pH AND pE MEASUREMENTS DURING METHANE BIOSYNTHESIS

F. G. Pohland and K. H. Mancy
Biotechnol. Bioengng, 11, pages 683–699 (1969)

The use and interpretation of the measurements of pH value and electrode potential in the analysis of anaerobic ecosystems are discussed, together with the associated limitations of the analytical methods. The application of such measurements to process control was considered feasible.

Keywords: pH, ORP, electrode potential, control and monitoring.

A MATHEMATICAL MODEL FOR THE CONTINUOUS CULTURE OF MICROORGANISMS UTILIZING INHIBITORY SUBSTRATES

Clemson Univ., S.C., Environmental Systems Engineering
J.F. Andrews

Biotechnology and Bioengineering, Vol. X, Issue 6, pages 707–723 (1968)

A mathematical model is presented describing the kinetics for both batch and continuous culture of microorganisms utilizing substances which limit growth at low concentrations and inhibit growth at higher concentrations. A key feature of the model is the use of an inhibition function (after Haldane) which relates substrate concentration to specific growth rate. A digital computer was used in simulation studies and it is shown that the primary result of inhibition by substrate in a batch culture is an increase in the lag time, whereas in continuous culture process instability may result. The model is also used to illustrate how process failure may occur during start-up of continuous-flow biological processes as a result of inhibition. The model should be of value in investigations of the stability of biological processes used for the treatment of certain industrial wastes which are known to be inhibitory to many of the organisms metabolizing them.

Keywords: mathematical models, microorganisms, kinetics, growth rates, cultures, biological treatment, waste treatment, eutrophication, water pollution effects, continuous culture, inhibitory substrates, growth kinetics, batch cultures, growth inhibition and substrate-limited growth.

ACCELERATED DIGESTION OF CONCENTRATED SLUDGE

Mississippi State Univ., State College, Dept. of Sanitary Engineering
A. Shindala, J.V. Dust and A.L. Champion

Water and Sewage Works, Vol. 47, No. 9, pages 329–332 (Sept. 1970)

A study was made of the digestion of concentrated domestic sludge. The purpose of the investigation was: (1) to determine successful digestion of thickened sludge; and (2) to evaluate optimum solids concentrations combined with optimum digestion periods that would produce acceptable volatile solids reductions. Sludges tested with solid concentrations of 5, 15, 25, and 35% were digested for loading periods of 30, 20, 15, and 10 days under constant mesophillic temperature conditions and displacement loadings. Digested sludge with a volatile matter content of 44% was used to start digesters. Conditions inside the digesters were checked every 4 days. Raw sludge used was concentrated to 15%, 25% and 35%. A sludge volume of 1/2 1 was used, and temperature was maintained between 92 deg and 95 deg F. The following parameters of the added sludge were known: (1) weight, (2) percentage of solids and (3) percent of volatile matter. Several factors were observed in order to avoid digester failure: (1) pH, (2) alkalinity, (3) volatile acids and (4) temperature of digestion. With these factors in mind the following control tests were performed on sludge: (1) volatile acids, (2) pH, (3) total alkalinity, (4) volatile solids and (5) total solids. The results showed that concentration had a definite effect upon digestion. Percentage reduction and volatile matter decreased with increased concentration for all loadings. From the data compiled during this study, the following conclusions are drawn: (1) volatile acids and alkalinity increased with increase in solids concentration, (2) pH remained constant indicating pH was not a function of

the increase in solids concentrations as long as alkalinity to volatile acids ratio was more than 1, (3) 15% solids produced maximum amount of gas per liter of sludge but 5% produced the most gas per unit of dry solids, (4) the percent reduction in volatile solids decreased with the increase in solids concentration, and (5) loadings of concentrated sludges up to 10 mg/day produced an acceptable volatile solids reduction.

Keywords: digestion process, sewage, sludge, anaerobic digestion, economics, alkalinity, hydrogen ion concentration, waste water treatment, thickening, volatile acids and temperature.

SOLUTION OF A SULFIDE TOXICITY PROBLEM IN A MUNICIPAL ANAEROBIC DIGESTER

Iowa State Univ., Ames
D.G. Green
Master's Thesis, 81 pages (1970)

After repeated attempts to start up several new two-state anaerobic digesters failed, a survey for sources of toxic materials was conducted, revealing that one major industry contributed 30% of the influent to the treatment plant. The industrial waste was very high in organic material, much of which was bactericidal compounds. Laboratory tests were then performed on the wastes, demonstrating that the failure in starting the digesters was not due to temperature control, pH control, or poor operation. Large amounts of hydrogen sulfide produced indicated the possibility of sulfide toxicity. Results also indicated that other toxic materials possibly were present, acting as synergistic toxins. Ferric chloride (FeCl3. 6H2O) added in a ratio of ferric chloride to total sulfur measured as sulfate (SO4=) of 2:3, was successful in controlling the toxicity, and no further start-up difficulties were encountered. Cost of the iron treatment was estimated at 45 cents/1000 gallons of sludge treated.

Keywords: anaerobic digestion, toxicity, sulfides, sludge, municipal wastes, industrial wastes, bactericides, laboratory tests, iron compounds, chemical precipitation, cost analysis, waste water treatment, synergism and digesters.

REPORT OF A STUDY OF THE METHANE FERMENTATION BETWEEN MESOPHILIC AND THERMOPHILIC TEMPERATURE RANGES

D.J. Hills and E.D. Schroeder
Wat. Wastes Engng, 6, No. 7, pages 47—69 (1969)

In laboratory experiments on the anaerobic digestion of sewage sludge in the temperature range 35°—52° C, the methane fermentation rate, volatile acids concentration, and total gas production rate were measured in 3 identical digestion systems under steady-state conditions at a selected temperature. All units failed or commenced to fail at about 42°—43° C, and on increasing the temperature in one unit to 52° C there was no resumption of gas production.

Keywords: temperature, methane production mesophilic and thermophilic.

ELECTRODE POTENTIALS—SIGNIFICANCE IN BIOLOGICAL SYSTEMS. 3. SLUDGE DIGESTION

H.A. Dirasian
Wat. Sewage Wks, 115, pages 505--511 (1968)

Electrode potential levels occurring during anaerobic digestion were studied in model digestion units under continuous-mixing conditions and under unmixed conditions. Sewage sludge from various plants was used, and the units were maintained at 35°C. Runs under continuous-mixing conditions were made to determine normal values of electrode potential for efficient digestion, and it was shown that if more positive or negative levels were maintained by special circuitry, the digestion process would deteriorate in proportion to the difference of the potential from normal. It was also shown that overloading and consequent increase in electrode potential caused the process to fail in a similar manner to that obtained by maintaining positive electrode levels by circuitry. In the unmixed experiments, 72 platinum electrodes were used to determine potentials at various points in the digestion unit; in preliminary studies potentials were found to decrease to normal except near the inlet position where they did not decrease sufficiently until 20 hours from the time of feeding.

Keywords: performance, ORP electrode potentials, mixed digesters, unmixed conditions and loading.

DYNAMIC MODEL OF THE ANAEROBIC PROCESS

Clemson Univ., S.C., Dept. of Environmental Systems Engineering
J.F. Andrews
Journal of Sanitary Engineering Division, American Society of Civil Engineers, Vol. 95, No. SA1, pages 95—116 (Feb. 1969)

Process stability has been the major problem associated with the anaerobic digestion process. A dynamic model which utilizes an inhibition function to predict the failure of an anaerobic digester was presented.

Keywords: anaerobic digestion, simulation analysis, inhibition, hydrogen ion concentration (pH), anaerobic bacteria, laboratory tests, waste water treatment, dynamic model, volatile acid concentration, process stability and pactorus.

FACTOR ANALYSIS AS AN AID IN AN ECOLOGICAL STUDY OF ANAEROBIC DIGESTION

National Inst. for Water Research, Pretoria (Africa)
D.F. Toerien, W.H.J. Hattingh, J.P. Kotze, P.C. Thiel and M.L. Siebert
Water Research (J Int Assn on Wat Poll Res), Vol. 3, No. 2, pages 129—140 (Feb 1969)

Interrelations between characteristics of an anaerobic ecosystem by means of principal component analysis of the linear correlation coefficient matrix of these characteristics is determined and described. Principal components (factors) were obtained which presented varied characteristics of the ecosystem. The behavior of the factors during a stress period was graphically demonstrated in relation to time. A three-dimensional model yielded visual representation of the behavior of three arbitrary chosen factors in relation to one another. It was concluded that factor analysis contributes much towards the determination of the relationships between characteristics and condenses the multitude of test correlations of the ecosystem into interpretable factors.

Keywords: anaerobic digestion, aerobic bacteria, ecological study, factor analysis, eigen-values, eigen-vectors, matrix, dehydrogenase enzymes, kinase enzyme, biotic and abiotic.

SUBSTRATE FLOW IN ANAEROBIC DIGESTION

National Inst. for Water Research, Pretoria (Africa)
D.F. Toerien, P.G. Thiel and W.A. Pretorius
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

The optimal utilization of anaerobic digestion is dependent on a knowledge of the mechanism of the process, since it forms the basis of kinetic evaluations of the process. Substrate flow in any biological treatment process depends on the organisms participating in the process, and proceeds at two levels namely, flow of substrate in single cells (intracellular substrate flow) and flow of substrate between cells (intercellular substrate flow). At least three different mechanisms might be involved in methanogenesis during anaerobic digestion. They are: (1) Single-step methanogenesis in which complex organics are decomposed directly to methane, (2) Dual-step methanogenesis in which intercellular substrate passes through the acid-forming and the methanogenic bacterial groups, and (3) Multi-step methanogenesis in which a symbiotic association of two bacterial species exists. The one attacks ethanol producing acetate and H2, while the other utilizes the H_2 together with CO2, to produce CH_4. It is concluded that if methanogenesis requires the activities of more than two groups of bacteria, another intermediate group of bacteria must exist in anaerobic digestion. The existence of such a group and its characteristics should be investigated. It is also concluded that although acetate is one of the major precursors of methane in anaerobic digestion, it is doubtful whether this reaction is 'growth-coupled'. This aspect should be investigated fully, since it is important in kinetic evaluations.

Keywords: digestion, anaerobic digestion, anaerobic conditioning, sludge treatment, flows, waste water treatment, sewage treatment, bacteria, methane, fermentation, microorganisms, cells and acetic acid.

THE pH TOLERANCE OF ANAEROBIC DIGESTION

New Mexico State Univ., Las Cruces
R.H. Clark and R.E. Speece
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

Eight laboratory anaerobic filters constructed from 5.5 in. ID, 36 in. plexiglass columns filled with 1-1 1/2 in. broken quartzite stone media were used to study the effect of non-optimum pH on methane fermentation. The reactor pH, methane production, and effluent Chemical Oxygen Demand (COD) were the primary parameters measured. The pH levels between 3.9 and 9.3 were studied for durations of 12 hours to 21 days. Results showed that: (1) Steady state acetate fermentation at pH levels as low as 4 was possible, although at a rate

less than would be attained with the same reactor and bacterial population in the optimum pH range. (2) Acetate fermentation in an anaerobic filter was not inhibited between pH 6 and 8. (3) The recovery of acetate fermentation after a pH drop to as low as 5.0 was complete and prompt if the drop duration was less than 12 hours but required more time than would be expected based on simple bacterial regeneration and was only pH dependent if the drop duration exceeded 3 days. (4) A pH of 9 essentially stopped acetate fermentation, but recovery was complete and prompt after optimum pH levels were restored.

Keywords: hydrogen ion concentration, digestion, anaerobic digestion, toxicity, methane, fermentation, acids, sludge, sludge treatment, sewage treatment, waste water treatment and chemical oxygen demand.

ANAEROBIC DIGESTION FAILURES

Bergen County Sewer Authority, Little Ferry, N.J.
S.A. Peterson and H.R. Zablatzky
Journal Water Pollution Control Federation, Vol. 40, No. 4, pages 581—585 (April 1968)

Two separate incidents of digester failure are discussed, along with the materials and methods used to help them recover. Parameters of pH, alkalinity, CO_2 content, volatile acids content, and gas production were continuously monitored and that data is presented in graphical form. Under-concentration of feed sludge may lead to failure by the depletion of alkaline buffering materials. Over concentration of feed sludge allows buildup of ammonium alkalinity to toxic levels. One of the essentials of good digester maintenance is early diagnosis of problems through close observance of the major parameters. Ideal sludge concentration varies from plant to plant and must be determined by the individual operator.

Keywords: anaerobic digestion, alkalinity, lagoons, hydrogen ion concentration, waste water treatment, sludge, sludge digestion, digestion (decomposition), isolation, ammonium alkalinity, thickeners, volatile acids, gas production, sodium hydroxide, potassium hydroxide, calcium oxide and gas agitation.

ANAEROBIC DIGESTION OF CHEMICALLY PRECIPITATE SLUDGE

Marquette Univ., Milwaukee, Wis.
T.P. Parrillc
Master's Thesis, 82 pages, 22 (August 1970)

Chemical precipitation of phosphates with aluminum and iron salts has been suggested as a method of combatting eutrophication of lakes. The sludges thus formed are bulky and difficult to handle. Three laboratory digesters mixed by gas recirculators were operated at a controlled temperature of 95 plus or minus 2F and brought to steady state on normal primary sludge. Two of the digesters were then fed chemically precipitated sludge while the third served as a control. The quantity and quality of gas produced, the volatile solids reduction, and pH changes were monitored and compared for all three digesters. Total soluable phosphorous was monitored both in the feed and in the digested sludge to determine if any release of phosphorous was taking place. These investigations revealed that: (1) chemically bound phosphorous was not released during anaerobic digestion; (2) no drastic effect on digester performance was observed except the inhibition of gassification in the units fed chemical sludge; (3) CO2 content was lower while N2 content and methane content were higher in gas produced from the chemical sludge; and (4) no adverse effects on pH or volatile matter destruction were observed.

Keywords: anaerobic digestion, phosphates, chemical precipitation, eutrophication, sludge, temperature, alkalinity, hydrogen ion concentration, iron, methane, carbon dioxide, nitrogen, waste water treatment, volatile solids reduction and aluminum.

MONITORING FOR LAS IN NORTHERN CALIFORNIA SLUDGE DIGESTERS

California Univ., Berkeley, Sanitary Engineering Research Lab.
S.A. Klein
Sanitary Engineering Research Laboratory Report No. 69-9

Accusations have been widespread that anionic detergents are often times responsible for digester failure. A number of digesters were carefully monitored and analyzed to determine whether or not LAS did cause digester upset. Work performed in England established the 1.0% (dry solids basis) level as being the critical level. Methylene blue active substances (MBAS) levels in California digesters were found to be 0.5% or less in the raw sludge. Circulating digester sludge was found to contain 200 to 400 mg/l (1.0 to 1.5% dry solids), also below the reported retardation level of 600 to 900 mg/l for digester sludge. Bottom sludge samples yielded an average of 1000 mg/l MBAS, only 0.5% MBAS on a dry solids basis due to the greater total solids concentration. Therefore, the effective parameter was taken to be reduced digester capacity and not LAS concentration. Although the cause of the unusual number of digester upsets during 1963—1967 remains unknown, trouble free performance since that time supplemented by the data obtained here essentially preclude LAS concentrations as the causative agent.

Keywords: anaerobic digestion, detergents, alkyl benzenesulfonates, linear alkylate sulfonates, biodegradation, anaerobic conditions, adsorption, sampling, monitoring, sands, California, waste water treatment, sludge digestion, digestion and digester failure.

PHYSICAL STRUCTURE OF ACTIVATED SLUDGE IN AEROBIC STABILIZATION

G. Laubenberger and L. Hartmann
Water Research, Vol. 5, No. 6, pages 335—341 (June 1971)

The change in the physical parameters of activated sludge undergoing aerobic stabilization was monitored by observing floc size, specific weight, and the A-value (Thomas 1954). Particle size was measuring using sieves of mesh sizes of 32, 50, 80, 100, 160 and 250 micro M. Specific weight was determined through use of a pyonometer, and the Thomas A-values (water-volume/sludge-solids-volume of floc) were calculated from the Thomas formulae. A stabilization time of ten days was used and both laboratory sludges and activated sludge from a municipal sewage plant were observed. Both the particle size and the A-values were observed to change as the organic content of the sludge decreased. Flocs formed of large particles or various size particles contained less stagnant water in the interstices than flocs formed of small particles. Also, the larger the particle size, the greater the effect of aerobic stabilization in reducing floc water content and increasing floc density. Although aerobic stabilization does lead to a denser floc with less water content, the differences in A-values of activated sludge flocs and inorganic chemical flocs are of the order of two magnitudes.

Keywords: activated sludge, aerobic treatment, sludge digestion, municipal wastes, aeration, flocculation, particle size, sieve analysis, analytical techniques, laboratory tests, density, wastewater treatment, sludge treatment, Thomas A-value, flocs, organic sludge, and inorganic sludge.

HIGH-RATE ROTARY VACUUM FILTRATION

Rutgers Univ., New Brunswick, Water Resources Ref. Inst.
F. W. Dittman
Rutgers Univ., 4 pages (1967)

An economic study of an existing waste treatment plant indicated thatsludge filtration might be an acceptable alternative to the existing process of transportation and ocean dumping, provided higher than usual filtration rates could be obtained. A study of several of the problems re variation in the filtration rate of aqueous calcium carbonate suspensions gave numerical values for an increase in the filtration rate that would result from operating a rotary filter at high speed with a very thin cake. Various means of applying energy to the membrane for rapid continuous separation of the thin filter cake are discussed.

Keywords: filtration, sludge, filters, sludge treatment, sewage treatment, sludge disposal, waste disposal, calcium carbonate, waste treatment, filtration rate, and sludge cake.

POLYMERS IN THE FILTRATION OF RAW SLUDGE

Kansas City Dept. of Water and Pollution Control, Mo.
G. J. Hopkins and R. L. Jackson
Journal Water Pollution Control Federation, Vol. 43, No. 4, pages 689—698 (April 1971)

The solids-handling facilities serving Kansas City's two major treatment plants have been in operation since 1966. Kansas City is the first known major U.S. city where the initial design of new sludge treatment facilities provided solely for the use of polymers as the sludge conditioning agent for vacuum filtration of raw sludge, followed by filtration of the filter cake. Initially, the system was set up to feed only cationic polymers, but operational difficulties soon dictated the addition of an anionic polymer. The operating staff, in conjunction with local consulting engineers, has resolved the operational problems that are inherent in early operations of large untested facilities. Chemical suppliers were required to test their products at the plant scale, as well as analytically. These data, combined with competitive bids, were used to select the chemicals to be purchased. At the present time, an operating cost of $2.20 per ton of dry solids has been calculated.

Keywords: sludge, dewatering, filtration, sludge treatment, separation techniques, mixing design criteria, automatic controls, cost analysis, wastewater treatment, incineration, polymers, sludge conditioning, and filter cake.

SOME EXPERIENCES IN THE CONSOLIDATION OF SURPLUS ACTIVATED SLUDGE

Manchester Corp. (England). Rivers Dept.
P. Brown and A. Thomas
Water Pollution Control, Vol. 68, No. 2, pages 203—211 (March-April 1969)

Increasing the proportion of activated sludge solids at the 68 MGD Davyholme Works of the City of Manchester from 17 to 46 percent resulted in thinner sludges being obtained from the sedimentation tanks due to a reduction in the amount of supernatant. A survey was made of methods to reduce sludge volumes including: polyelectrolyte flocculants, pressure flotation, centrifugation and heat treatment. Polyelectrolytes increased the settling rate of both digested and activated sludge, but had no effect on ultimate solids control. Pressure flotation yielded sludge solids contents of 2.5 to 5.0 percent. Several centrifugation methods produced sludges of between 8 and 10 percent solids. Heat treatment followed by 24 hours of settling produced sludges of 7.7 to 12.2 percent solids. Modification made on the plant was to divert excess activated sludge from the primary settling tanks to separate consolidation tanks using periodic sludge withdrawal. The consolidated activated sludges contained 6.5 percent solids. The activated sludge used in the trials had treated sewage containing large amounts of chemical wastes.

Keywords: activated sludge, sludge disposal, consolidation, centrifugation, flotation, heat treatment, sludge treatment, sludge digestion, sludge, polyelectrolytes, and supernatant.

THICKENING OF SEWAGE SLUDGE

Stalmann and Volker. Gas- u.
WassFach, 108, pages 485—487 (1967)

Following the experiments which were carried out by the Enschergenossenschaft on the activated-sludge process (see also Wat. Pollut. Abstr., 1966, 39, Abstr. No. 1645), pilot-plant and laboratory experiments were carried out on sludge from the Emscher treatment plant to determine the most effective method for sludge thickening. Considering the characteristics of the sludge, the authors claim that continuous operation is most effective and details, including graphical illustrations, are given of the methods and equipment used. To ensure smooth operation it is essential that the sedimentation tanks are wide enough to permit free flowing operations and that they are positioned in series to give a constant equilibrium between the quantity of sludge flowing in and the quantity withdrawn. The decanted liquor is then circulated gently to the consolidation zone, where a type of "filtration" occurs, effecting clarification of the overflowing water. Varying concentrations of the incoming sewage sludge did not affect the thickening process and results of full-scale operations confirmed those of pilot-plant experiments.

Keywords: thickening, sewage, continuous, sedimentation, clarification, pilot plant, full scale, and filtration.

CENTRIFUGATION OF WASTE SLUDGES

Dorr-Oliver, Inc., Stamford, Conn.
E. Albertson and E. E. Guidi, Jr.
J. Water Pollut Contr Federation, Vol. 41, No. 4, pages 607—628 (April 1969)

Sludge centrifugation with a description of the principles of the centrifuge are reviewed. Results of tests on the solid bowl process variables of feed rate, particle size and density, feed consistency, temperature and chemical aids are reported. The tests were run at 70 sites throughout the U.S.A. on raw primary and secondary sludges, digested primary and secondary pulp and paper wastes and water softening sludges. The results of the tests indicate that a long-bowl centrifuge can handle all types of sludges and can produce a solids concentration as high as or higher than vacuum filters at costs not exceeding those for vacuum filtration. The use of centrifugation for dewatering sludges will increase because of machine improvements.

Keywords: centrifugation, sludge, dewatering, cost comparisons, design criteria, flow rates, sludge thickening, solid bowl centrifuges, long-bowl centrifuges, pool volume, bowl speed, process variables, and feed rates.

SOLIDS SEPARATION BY ULTRAFILTRATION FOR CONCENTRATED ACTIVATED SLUDGE

Syracuse Univ., N.Y. Bioenvironmental Engineering Div.
F. W. Hardt, L. S. Clesceri, N. L. Nemerow and D. R. Washington
Journal Water Pollution Control Federation, Vol. 42, No. 12, pages 2135—2148 (Dec. 1970)

An investigation of the feasibility of separating the suspended material from the mixed liquor and recyling this material back to the biological reactor as a means of treating high-BOD wastes was conducted. This involved passing feedwater at an elevated pressure across synthetic membranes where the larger dissolved solids and suspended material are retained by the membrane and recycled back through the activated sludge plant. Analytical methods included daily monitoring of the COD, total and orthophosphates, TOC, MLVSS, SS, inorganic solids, respiration rate, and the molecular size of the dissolved solids in the mixed liquor and the ultrafiltrate. This process showed a 98% COD reduction but had a gradual accumulation of cell degradation products in the biological reactor. The membranes used detained DS of molecular weights greater than 1000 which essentially removes all bacterial solids from the effluent stream.

Keywords: filtration, activated sludge, biochemical oxygen demand, microorganisms, membranes, filters, pressure, hydrogen ion concentration, chemical oxygen demand, phosphorus, respiration, gels, solvents, solutes, waste water treatment, mixed liquor, volatile suspended solids, ultrafiltration, ultrafiltrate flux, total organic carbon, and cell lysis.

INSTRUMENTS FOR DETERMINING THE CHARACTERISTICS OF SLUDGE DEWATERING

Weiland, N. Abwass
Technik, 21, No. 3 (1970) III (in German)

Instruments are reviewed which were developed by various workers to determine the filtrability of sewage sludges in sludge dewatering. Instruments described include an automatic recorder determining the capillary suction time, a laboratory air-pressure filter press, which works on the same principle as the chamber filter press, and an automatic sampler to obtain representative samples of the dewatered sludge.

Keywords: automatic, instruments, filtrability, sewage, capillary suction time, filter press, and sampler.

SLUDGE DENSITY CONTROL BY ULTRASONICS

Southwest Suburban Sewer District, Normandy Park, Wash.
E. R. Sironea and D. Lee
Journal Water Pollution Control Federation, Vol. 42, No. 2, pages 298—201 (Feb. 1970)

A 'sludge density controller' for control of the pumping cycle of sludge pumps to digesters was designed and installed at a wastewater treatment plant. The control device uses sound waves to sense the density of the pumped sludge, and stops the pumps when the percent solids drop below the desired value. This prevents the pumping of excess water into the digesters. The system includes an ultrasonic sensor and electronic control unit. The ultrasonic sensor contains a piezoelectric crystal transmitter and a receiver separated by a gap through which the sludge is passed. The ultrasonic sound waves transmitted across the gap are attenuated in proportion to the percent solids present. The electronic control unit activates the sensor and interprets the receiver output to control the pump relay, stopping the pump cycle when the sludge density drops below the desired percent solids. The initial design and subsequent modifications incorporated in the second model are described. The system is presently installed and operating trouble-free at the Miller Creek sewage treatment plant, Normandy, Washington. The approximate cost of the unit installed is $465.

Keywords: sludge, pumping, control systems, sound waves, automatic control, sludge digestion, waste water treatment, Washington, ultrasonics, and sludge digestion.

PROCESS CONTROL OF CENTRIFUGE OPERATIONS

Delaval Separator Co., Pough-keepsie, N.Y.
D. M. Landis
Chemical Engineering Progress, Vol. 66, No. 1, pages 51—53 (Jan. 1970)

Practical process control is a must if scale-up based on specific operating conditions is to result in satisfactory operation of the centrifuge. Centrifuges are generally supplied based on laboratory, pilot plant or field tests of the centrifuge performing the desired separations of the specific wastes to be treated. The choice of candidates for these tests is based upon: economics, type of separation desired, particle size of solids, solid content of feed, relative density of components, capacity desired and special considerations (pH, temperature and configuration). If the wastes change drastically from those tested without the operator's knowledge, the centrifuge will not operate with the desired capacity of efficiency. Various control systems are available to monitor viscosity, solids content, particle size and turbidity. In addition, automatic alarm and shut-down devices are available which can be coupled with these monitors to effect process control. Process control is vital to all process operations and extremely so in utilizing centrifugal separators to their maximum work capability and work efficiency.

Keywords: waste water treatment, industrial wastes, municipal wastes, dewatering, automatic control, centrifugation, design, laboratory tests, pilot plants, on-site tests, hydrogen ion concentration, temperature, viscosity, turbidity, particle size configuration, and solids content.

EFFECTS OF SLUDGE CONDITIONING WITH LIME ON DEWATERING

Lurgi Gesellschaft fuer Chemotechnik m. b. H., Frankfort am Main (West Germany)
H. Sontheimer
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 165—180 (1966)

A new sludge dewatering process, known as the Carbofloc process has been developed. This process is suitable for handling both fresh and digested mixed sludges, and has already been successfully applied on a commercial scale. Lime is added to the incoming sludge, and contributes not only the normal dehydrating effect of lime itself, but also a lime bonding effect. Every sludge has a different lime-bonding capacity, and this characteristic is a major variable in lime addition sludge-dewatering processes. After the lime addition, with its subsequent dehydrating effect, the mixture is neutralized with CO_2, the end result being the conversion of free calcium hydroxide to insoluble calcium carbonate. When this neutralization is carried to the point where fixed calcium is converted to $CaCO_3$, transcoagulation takes place, resulting in improved thickening properties and higher solids content during filtration and centrifuging.

Keywords: lime, dewatering, centrifugation, neutralization, filtration, flocculation, coagulation, sedimentation, chemical precipitation, alkalinity, hydrogen ion concentration, waste water treatment, sludge, sludge treatment, lime bonding capacity, lime addition, vacuum filtration, thickening, and reaction time.

FORMAL DISCUSSION OF 'EFFECTS OF SLUDGE CONDITIONING WITH LIME ON DEWATERING'

Ruhrverband, Essen (West Germany)
U. K. Moller
Proceedings of the Third International Conference on Water Pollution Research, Munich, Germany, pages 180—187 (1966)

Three basic types of sludge water have been dealt with. In order of increasing difficulty of separation, they are interspace water, adhesion and capillary water, and adsorption and internal water. Work is required to over come the liquid-solid binding forces to dewater the sludge. The influence of gravity is enough to remove interspace water, but mechanical dewatering devices are needed to cope with the other waters. Calcium hydroxide, when used in the presence of metal salts or carbon dioxide, reduces the binding forces which hold the liquid to the solids. The effective range, however, is restricted to the water binding. The overall investigations did confirm the utility of lime as an effective and economical aid in sludge dewatering.

Keywords: dewatering, calcium hydroxide, lime, vacuum drying, adsorption, adhesion, capillary water, iron compounds, colloids, aeration, flocculation, coagulation, activated sludge, sewage, waste water treatment, metal hydroxides, filter cake, and electrostatics.

AN INVESTIGATION OF SLUDGE DEWATERING RATES

Massachusetts University., Amherst
J. H. Nebiker, T. G. Sanders and D. D. Adrain
Journal of the Water Pollution Control Federation, Vol. 41, No. 8 pages R255—R266 (Aug. 1969)

Waste water sludge disposal is one of the most vexing problems of water pollution control. Nearly 25 to 65 percent of total capital and operating costs of primary and secondary treatment plants are expended in handling sludge. It therefore becomes necessary to place more emphasis on volume reductions of the sludge prior to its ultimate disposal. Nearly 72% of treatment plants in the United States utilize sludge drying beds. Past research and gravity dewatering shows very few formulations equating dewatering rates to inherent sludge characteristics. The paper presents theoretical analysis relating depth of sludge and time with the solids-content, specific resistance and coefficient of compressibility. The developed formula is verified experimentally. Further, all parameters are readily determinable by simple laboratory tests, thus presenting an accurate analytical method to predict gravity dewatering and provide a rational basis for selection and optimization of a sludge dewatering system.

Keywords: design, dewatering, sludge disposal, waste water treatment, digestion, filtration, theoretical analysis, activated sludge, sludge treatment, dewatering rate, drying beds, pilot-study, specific resistance, and media factor.

CENTRIFUGATION

Weston (Roy F.), West Chester, Pa.
J. H. Daugherty and D. N. Bibbo
In: Water Quality Improvement by Physical and Chemical Process, University of Texas Press, Austin, pages 388—393 (1970)

The three types of most widely used centrifuges in the field of waste water treatment are solid bowl, disc, and basket. Each perform one of three functions: clarification, classification or separation. Clarification is the process of removing the solids from a slurry phase where either the supernatant liquid or the solids are to be recovered. Classification is the process of removing solid particles of specific size from a liquid phase. Separation is the process of splitting a liquid into two fractions. In all three processes a difference in density must exist

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for the application to be feasible. In waste water treatment primary interest is in clarification or the removal of solids from a sludge or slurry, thereby reducing the volume for easier disposal. Centrifuges have been used extensively in the dewatering of primary, secondary and combined sludge and for oil recovery, slime sludge dewatering and by-products recovery. The solid-bowl machine is generally best suited for dewatering the solids involved in primary clarification. Centrifuges operating on primary sludge and achieving greater than 90% solids recovery have a cake discharge with a solids content of about 20 to 25%. Suggestions are given for specifications and information which may be presented to the equipment manufacturers when selecting a centrifuge for a specific use.

Keywords: sludge, sludge treatment, centrifugation, specification, waste water treatment, sewage treatment, performance, design, and activated sludge.

STUDIES ON THE VACUUM FILTRATION OF SEWAGE SLUDGES

Water Pollution Research Lab., Stevenage (England)
R. S. Gale and R. C. Baskerville
Journal of the Institute of Water Pollution Control, No. 5 (1970) (Water Pollution Research Laboratory Reprint No. 603)

A mathematical model of the vacuum filtration process was developed. This model deviated from previously formulated models in that: (1) it recognizes that the filtration parameter usually calculated from Buchner funnel tests is not the true specific resistance but an apparent specific resistance; (2) to allow for this descrepancy, a function of the solids content of the sludge and the solids content of the cake during formation is introduced; (3) no equation allowing for the resistance of the filter medium is presented. The equation was successfully used to predict the yield from both a pilot scale and a full scale facility within plus or minus 30%, a remarkable achievement considering the fact that a proportion of the cake dropped off under all conditions. The fact that stable operation was obtained even with substantial drop-off indicated that the solids content increase of the sludge almost completely compensated for the drop-off. The investigations also emphasize d that optimum conditions could be obtained only by a compromise between: (1) filter speed and cake thickness; (2) submergence and cake moisture content; (3) chemical conditioning and both moisture content and yield and (4) solids content increase and moisture content.

Keywords: vacuum drying, filtration, sludge, dewatering, moisture, flocculation, mathematical models, shear, mixing, pilot plants, waste water treatment, sewage, model studies, specific resistance, filter cloth, polyelectrolytes, and vacuum filtration.

POLYELECTROLYTES IN THE DEWATERING OF SEWAGE SLUDGES

Water Pollution Research Lab., Stevenage (England)
R. S. Gale and R. C. Baskerville
Filtration and Separation (Jan—Feb. 1970) (Water Pollution Research Laboratory Reprint No. 578)

Nine manufacturing firms participated in an evaluation of the economic and technical feasibility of using polyelectrolytes, instead of lime and ferric sulfate or aluminum chlorohydrate, as filter aids. Each company was allowed to submit two compounds for each type of sludge tested, and economic evaluations were assembled. Concentrations of the stock chemicals to be supplied were constrained such that if 20 ml of chemical was added to 100 ml of sludge containing 5% dry solids, then the cost does would be 200 shillings per ton of dry solids. The wide variety of results obtained indicated that performance varied with: (1) type of sludge treated; (2) dosage; (3) pH; (4) age of solution; (5) mixing; and (6) type of water used to prepare the polyelectrolyte solutions. Difficulty was also experienced in adapting laboratory information to full scale design due to uncertainties in scale up. However, the work performed has provided more information as to which variables need to be closely monitored in subsequent testing.

Keywords: sludge treatment, separation techniques, lime, dewatering, coagulation, filtration, hydrogen ion concentration, temperature, mixing, shear, vacuum drying, ammonia, electrolytes, waste water treatment, polyelectrolytes, and aluminum chlorohydrate.

HIGH TEMPERATURE TREATMENT OF SEWAGE SLUDGES

Water Pollution Research Lab., Stevenage (England)
W. J. Fisher and J. D. Swanwick
Water Pollution Control, Vol. 70, No. 3, pages 355—373 (1971)

Until recently, heat-treatment of sewage sludge had been limited to a few works treating difficult sludges by batch processing. The development of a continuous plant has stimulated interest in the process and today about thirty plants have been or are about to be built in the United Kingdom. Laboratory tests have been made on heat treating 12 different sludges and also on the partial (about 15%) wet air oxidation of these same sludges at 170, 200, and 230° C. The results of these tests are: (1) all 12 sludges could be made readily filtrable by heat treatment or partial wet air oxidation; (2) the suspended solids contents of all sludges, particularly secondary sludges, decreased on treatment; (3) a corollary to this is that the liquors from the secondary sludges were the strongest; (4) sludge type and sludge strength were the most important factors in determining liquor strength; (5) wet oxidation was more effective in reducing amount and COD of suspended solids; and (6) in general, there seemed to be little difference between the effect of heat treatment and wet air oxidation on the most important characteristics, namely filtrability of sludge and strength and treatability of liquor.

Keywords: sludge treatment, heat treatment, chemical oxygen demand, biochemical oxygen demand, laboratory tests, autoclaves, suspended load, waste water treatment, wet-air oxidation, filtrability, and liquor strength.

DEWATERING OF SEWAGE SLUDGES BY HEAT TREATMENT

J. G. Everett and R. B. Brooks
Wat. Pollut. Control, Lond., pages 70, 1458—1466 (1971)

Further studies are reported on the effect of heat treatment on the filtrability of activated, mixed, humus, and cold-digested sludges (see also Wat. Pollut. Abstr., 1970, 43, Abstr. No. 1376), and time-temperature relations are derived for conditioning these sludges to reasonable, low, and very low specific resistance values. It was found that variations in ash content, initial specific resistance, and time of sampling had little effect on the reduction of specific resistance by heat treatment. A poorly-digested cold-digested sludge was easier to treat than a well-digested warm-digested sludge.

Keywords: heat treatment, filtrability, sludge and conditioning.

HEAT TREATMENT OF SEWAGE SLUDGES

University Coll. of South Wales and Monmouthshire, Cardiff. Dept. of Mechanical Engineering
R. B. Brooks
Water Pollution Control, Vol. 69, pages 221—231 (1970)

The object of the work was to obtain data which could be used to predict both the degree of sludge conditioning and the type of liquor produced from a variety of sludges in a full-scale plant. A comparison is made between laboratory and full-scale treatment. The laboratory results were similar in all respects to those of full-scale operation. Comparison of activated sludges from different localities conditioned to the same extent gave similar liquors when treated. The concentrations of individual components in a heat treatment liquor increased in proportion to the feed solids concentration. The COD was related to the dissolved solids (DS) by the relationship COD=1.234 +2026 (mg/l). The organic N content of heat treated liquor was proportional to the DS, there being one relationship for activated sludge and others for humus, primary, activated and digested sludges. The production of ammonia N as a percentage of the total soluble nitrogen, increases with reaction temperature and holding time. Reference is made to the use of activated carbon, coal, and additives. The calorific value of heat treated sludge was slightly higher than that of untreated sludge. Calculations have shown that all the potential heat is recovered from a sludge. A 3% sludge feed could produce a thermally self sustaining process.

Keywords: heat treatment, sewage sludge, chemical oxygen demand, dissolved solid, biological treatment, additives, solvent extraction, evaporation, nitrogen, ammonia, sewage treatment, waste water treatment, liquor, full scale plant, laboratory treatment and calorific value.

CONSIDERATIONS IN DIGESTED SLUDGE ELUTRIATION

Canadian-British Engineering Consultants, Ltd.
T. G. Scott
Water and Pollution Control, Vol. 107, No. 10 pages 419 (Oct 1969)

The elutriation process was considered in solving the problem of sewage sludge disposal. The elutriation tank at the North Toronto Sewage Treatment Plant was fitted with a thickener mechanism. Plant effluent was used as elutriation wash water and mixed with the digested sludge in ratios varying from two to one, to eight to one. Satisfactory filtration was obtained on the vacuum filter using both a chemical dosage of ferric chloride at the rate of 4% by weight of the solids filtered along with 6.5% lime and spent pickle liquor along with 10% lime. A substantial reduction in conditioning chemical demand by the removal of as much as 80% of the digested sludge alkalinity was noted. Problems of filtrate disposal were also eliminated as the filtrate was returned to the elutriation tank.

Keywords: sludge disposal, sludge treatment, filtration, anaerobic digestion, lime sewage treatment, waste water treatment, elutriation, vacuum filtration, ferric chloride and spent pickle liquor.

THERMAL CONDITIONING OF SEWAGE SLUDGE

Zimpro, Inc., Rothschild, Wis.
G. H. Teletzke
Preprint, presented at 44th Annual Conference of Water Pollution Control Federation, Session 24, No. 2 (Oct. 7, 1971)

Thermal conditioning of sewage sludge to improve dewatering has become an accepted method of sludge treatment because of the desirable characteristics of the dewatered end product produced and the economy of operation achieved when compared to chemical conditioning. Thermal conditioning with the addition of air provides some opportunity for oxidation, and also provides improved heat exchange, odor control, and flexibility. Thermal treatment produces a drainable residue by solubilizing and hydroyzing some complex organics which contribute a

BOD to the drainage liquor which must be removed. Operating data from Zimpro, Inc., thermal sludge conditioning plants in operation indicate that the drainage liquors, although high in BOD and nitrogen content, do not produce a significantly detected effect on the effluent from a conventionally operated activated sludge plant. For one plant the return of thermally treated sludge drainage liquor represented a recirculating load of about 0.5% of the sewage flow, 13% of the influent BOD, and 15% of the influent total nitrogen on an annual average basis.

Keywords: waste water treatment, activated sludge, sludge treatment, sludge disposal, oxidation, heat treatment, dewatering, chemical sludge treatment, cost comparison, nutrients, thermal conditioning, wet oxidation, odor control and nutrient recirculation.

CHEMICAL CONDITIONING OF BIOLOGICAL SLUDGES FOR VACUUM FILTRATION

Notre Dame Univ., Ind.
M. W. Tenney, W. F. Echelberger, Jr., J. J. Coffey and T. J. McAloon
Journal of the Water Pollution Control Federation, Vol. 42, No. 2, pages R1—20 (Feb 1970)

Polymeric flocculation produced biologically as a properly operating activated sludge process are not effective as sludge conditioners of waste sludge for dewatering by vacuum filtration. It is necessary to add chemical conditioners or synthetic organic polyelectrolytes to structure properly the waste activated by the carriage waste water quality parameters of pH, alkalinity, and phosphate concentration; and the sludge parameters of solid concentration, storage lime, and primary sludge ratio. The optimum pH for effective conditioning of the sludges tested was in the range of 6.0 to 11 for iron (III) and 4.5 to 5.5 for aluminum (III). An increase in either alkalinity, phosphate concentration, solids concentration, storage time, and primary sludge mix ratio required an increase in conditioner dosage necessary to enhance the dewatering of waste activated sludge.

Keywords: activated sludge, dewatering, flocculation, sewage treatment, sludge, vacuum drying, filtration, sludge treatment, waste water treatment, conditioning, polyelectrolytes, chemical treatment, flocculants, flocculating and sludge drying.

THERMAL TREATMENT OF SEWAGE SLUDGE

A. Bjorkman
Fourth International Congress of the International Research Group on Refuse Disposal, Proceedings, Bosel (June 2-5, 1969) N. P., N. D., pages 670—681

Thermal treatment plays a growing role in the disposal of sewage sludge. It is used to pasteurized sewage for agricultural use. Hygienists recommend a temperature of 70 deg C for 20-25 minutes for pasteurization. Heat and pressure coagulate the solid materials contained in sludge, destroy the cell walls and release the strong binding of sludge water to solid materials. Treatment at 260 deg C and under 15 atmospheres pressure allows mechanical dehydration processes to obtain residual water content of 40-44%. Heat treatment is also applied in several drying processes such as multiple hearth dryers, drying drums, flash drying systems or a belt dryer. If the sewage cannot be used it can be incinerated and the smallest possible residues then disposed of. Fluidized bed incineration and wet incineration are described. Liquid or dehydrated sludge can also be incinerated in appropriate devices jointly with good results.

Keywords: dehydration, incineration, sludge, sewage, oxidation, sludge treatment, sludge disposal, hygienization, thermal treatment, raw sewage, wet incineration and fluidized bed.

THICKENING CHARACTERISTICS OF ACTIVATED SLUDGE

Illinois Univ., Urbana
R. I. Dick
Advances in Water Pollution Research, Proceedings Fourth International Conference on Water Pollution Research, held in Prague, Czechoslovakia (April 21-25, 1969) London, Pergamon Press, Ltd, Sec II, Paper 18 (September 1968)

The settling characteristics of activated sludge differ from those of the ideal suspension on which gravity thickening theories are based. The 'non-ideal' behavior of activated sludge was interpreted in terms of the rheological properties of the suspension. A conceptual model of the hypothesized mechanism of subsidence of activated sludge was developed based on an analysis of forces acting on a mass of sludge. The resulting mathematical expression was inconsistent with prevailing theories of thickening, but was in close agreement with the observed settling behavior of activated sludge. The relative magnitude of the interparticle force was shown to be related to the yield strength of the sludge. It was concluded that the reason activated sludge failed to conform to prevailing theories of thickening was that it had a yield strength at ordinary mixed liquor suspended solids concentrations. The interparticle forces cause a reduction in settling velocity which is not considered in present theories relating to the area requirement for thickeners. The area of the thickening portion of a settling basin need not be considered to be inalterably established by the settling velocity of the rate-limiting concentration of activated sludge. The area can be reduced, or the capacity of an existing basin can be increased, by minimizing the reduction in settling velocity due to interparticle forces with the sludge, by controlling the depth and mixing conditions in the settling basin.

Keywords: activated sludge, consolidation, areal, mathematical models, rheology, sedimentation, settling velocity, sludge, yield strength and characteristics thickening.

FREEZING METHODS USED TO CONDITION ACTIVATED SLUDGE

Rex Chainbelt Inc., Milwaukee, Wis.
W. J. Katz and D. G. Mason
Water and Sewage Works, Vol. 117, No. 4, pages 110—114 (April 1970)

During the last few years a renewed attention has been placed on physical methods of sludge conditioning in an attempt to eliminate the need for chemical conditioners. The freezing of activated sludge causes the suspended solids to agglomerate and form relatively large floc particles. Upon thawing, these floc particles separate rapidly leaving a clear supernatant and occupy significantly less volume than before freezing. A pilot scale study was made to determine the effectiveness of freezing as a conditioner of activated sludge. The sludge concentrations used during the study ranged from 1 to 2.5%. After freezing the sludge was thawed and gravity filtered by various size wire screens, 140-24 mesh placed on a 9 cm buchner funnel. The screens had an effective area of 0.0575 sq. ft. Results of this study showed that a solid production rate of 36 to 57 lbs of dry solids per sq ft per hour was attainable. This figure is 10 to 20 times higher than that which would be expected from vacuum filtration of the same sludge. The filtrate quality obtained was less than 250 mg/l of suspended solids. This compares with a vacuum filter filtrate of 500 mg/l to 10,000 mg/l. Despite the encouraging results obtained by freezing conditioning methods development of the process was limited for the following reasons: (1) high cost and consumption of power, (2) high capital and operating costs and (3) frequent washing of filter media.

Keywords: sludge treatment, filtration, freeze-thaw test, pilot plants, freezing, activated sludge, dissolved solids, suspended solids, conditioning, loading, filter cake, wire screen cloth.

AN ASSESSMENT OF POLYELECTROLYTES FOR SLUDGE CONDITIONING AT WORTHING

Borough of Worthing (England)
R. E. Sleeth
Water Pollution Control, Vol. 69, No. 1, pages 31—38

Reten, Floccotan, Magnafloc, and Decapol were studied in full scale plant experiments to assess their relative merits for sludge conditioning. Sludge was collected from two treatment plants, one with a 1.3 mgd capacity, and one of 4.8 mgd capacity. The tests were performed to determine the validity of claims made about the polyelectrolytes. These advantages included: (1) polyelectrolytes are inert and they would be less susceptible to bacterial inhibition; (2) only a single chemical would be used, facilitating control; (3) reduced chemical dosages would reduce storage requirements; (4) polyelectrolytes, in a clean white powder form, would improve handling conditions; and (5) existing plants could use polyelectrolytes without extensive modification. Disadvantages known to exist were: (1) a special procedure was needed to prepare solutions of the chemical for introduction to the waste; and (2) difficulties might be encountered in controlling the addition of small amounts of an expensive material. Test results showed that all polyelectrolytes performed better than lime and copperas, with Floccotan being the optimum for this particular application. In addition, estimated savings based on initial performance would be approximately 1500 pounds per year. The validity of all originally claimed advantages was substantiated, while the disadvantages proved to be insignificant.

Keywords: sludge, dewatering, cost comparisons, lime, filtration, mixing, storage, waste water treatment, electrolytes, sludge treatment, polyelectrolytes, sludge conditioning, floccotan, decapol, reten and magnafloc.

DEWATERING OF WASTEWATER SLUDGE BY HEAT TREATMENT

J.G. Everett
Journal Water Pollution Control Fed., 44, 92 (1972)

A study of the effects of time and temperature of heat treatment of sludge on specific resistance to filtration showed that activated sludge became easily dewaterable within 40 minutes when subjected to 190°C. Temperatures above 210°C effected no better results than did 210°C except at very short holding times. Results for primary/activated sludge and humus sludge were similar, but cold digested sludge had good filtration characteristics after heat treatment at only 160°C. Final specific resistances were of the order of 10^{11} m/kg. For all sludges, heat treatment effects reduction of specific resistance by destroying the structureal integrity of microorganisms, thus preventing them from packing together. Higher temperatures and longer holding time yield more cell destruction and lower specific resistance.

Keywords: dewatering, heating, heat treatment, sludge, temperature, time and treatment.

TERMINAL WASTE TREATMENT AND SLUDGE DISPOSAL METHODS

DOOR-Oliver, Inc., Stamford, Conn., Industrial Water Projects Div.
R. R. Evans
Paper Trade Journal, Vol. 154, No. 31, pages 28—31 (August 3, 1970)

The Farrar heat treatment method has been developed for the treatment of secondary sludge. Vacuum filtration or centrifugation of untreated sludge results in a cake of only 15 to 20% dry solids even after an expenditure of $15 per ton of dry solids for polymers. Settling tests have demonstrated that the same type of sludge, after heat treatment, will settle by gravity of 25% of its original volume, and can be centrifuged to 35 to 40% dry solids content without the use of chemicals. Recovery of solids is between 92 and 97%. The Fluo-solids incinerator has also been developed to handle the incineration of such sludges by the fluidized bed method. This type of incineration is (1) simple and reliable; (2) able to handle both slurries and cakes; (3) allows selection and close maintenance of bed temperature; (4) has fast start-up and shut-down characteristics with no power or fuel required in the stand-by mode; (5) provides good effluent control; and (6) is easily automated. Cost analyses for these units in various combinations of biological treatment methods are presented.

PERFORMANCE OF DEEP TRICKLING FILTERS BY FIVE METHODS

Regional Inst. of Tech., Jamshedpur (India)
V. Hanumanulu
Journal Water Pollution Control Federation, Vol. 42, No. 8, pages 1446-1457 (August 1970)

The applicability of five methods for predicting the performance of deep trickling filters was studied: Velz, National Research Council, Ten States, Eckenfelder, and Galler and Gotaas. It was concluded that Velz law cannot be applied beyond a filter depth of 6 feet or where there is recirculation. The NRC formula underestimates the performance because the full effect of the depth of the filter is brought into play by recirculation. Efficiency calculated by the Ten States formula depended only on recirculation and in comparison with Velz and NRC formulas, predicts results that are closer to observed values. The Eckenfelder formula gave the best predicted values in the case of filter with recirculation. Efficiencies predicted by the Eckenfelder formula in the case of a filter without recirculation are far from the actual case. The values predicted by the Galler and Gotaas formula are only slightly better than those found by the Eckenfelder formula in the case of a filter without recirculation. In the case of a filter with recirculation, the Galler and Gotaas formula is close to the Eckenfelder formula. If the Galler and Gotaas formula is modified so that the depth term exponent is a linear function of recirculation volume, it becomes equally applicable to filters with and without recirculation.

Keywords: trickling filters, waste water treatment, design, performance, sewage treatment, filters, data collection, efficiencies, formulas, and recirculation.

OXYGEN UPTAKE AND MECHANISM OF SUBSTRATE PURIFICATION IN A MODEL TRICKLING FILTER

Cornell Univ., Ithaca, N.Y.
P. Monadjemi and V.C. Behn
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

A mathematical formulation is presented modeling the activity of the trickling filter. The basic assumptions in the development of this formulation are: (1) the flow of each individual element approximated to be of cylindrical shape is laminar with molecular diffusion as the prevailing means of mass transfer in the liquid layer, (2) at the point of contact of each element with the one immediately above or below it mixing of the liquid occurs, (3) the available active surface of slime film and the quality of it is constant in each element and from element to element for the biochemical oxygenization is not rate determining, (4) the substrate used is in the form of soluble nutrient, (5) the filter elements are packed in cubical fashion, (6) the waste has only one single compound. The mathematical model developed shows that the log of the portion of the substrate remaining is a linear function of depth. The oxygen uptake model is developed based on the same or similar assumptions. A dissolved oxygen profile was obtained using glucose as a substrate. The oxygen uptake in the filter was in the order of 10 mg of O_2 per hour per gram of slime film. Calculations for the top sections indicate that the uptake was about 13.6 mg O_2 per hour per gram of slime film and for the bottom sections 7.1 mg O_2 per hour per gram.

Keywords: trickling filters, mathematical models, depth, films, slime, dissolved oxygen filtration, chemical oxygen demand, sewage treatment, waste water treatment, oxygen demand, oxygen uptake, and purification.

ORGANIC AND LIQUID RETENTION TIME IN A TRICKLING FILTER FORMULATION

West Pakistan Univ. of Engineering and Technology, Lahore (Pakistan)
M.I. Sheikh
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

In spite of its extensive use the design of filters has largely remained empirical and there is not commonly accepted theory of filter performance based on practical and theoretical grounds. Therefore fundamental research was made to study the influence of the many variables affecting the filter process. The investigations were divided into 2 phases: (1) liquid retention time studies on laboratory and pilot scale filters and (2) organic retention time studies on specially built experimental filters. Each pilot filter has an internal diameter of 6 feet and a total height of 11 feet and was operated at hydraulic loadings of 3,570 and 140 gal/yd cu/day. The filter medium used was 2 inch stone with specific surface area of 23.8 ft sq/ft cu. The lab scale filters were 6 in. in diameter and 4 feet long, and were fed intermitantly at 5 minute intervals at the same loadings described above. They contained 3/4 inch and 1/4 inch sizes. The filter used for the organic retention time studies was an 18 inch diameter and a 6 foot depth reinforced concrete pipe; and was operated at a loading of 35 gal/yd cu/day. Br 82 was found to be the most suitable of the radio isotope tracers used for measurement of liquid retention time. Median time was found to be inversely proportional to the 0.87 power of the hydraulic surface loading and proportional to the filter depth and specific surface area of the filter medium. Up to 93% of the tracer carbon 14 was removed in about 30 minutes in the first foot of the filter.

Keywords: trickling filter, tracers, radioisotopes, sewage treatment, formulation, retention, carbon radioisotopes, depth, filtration, design, pilot plants, glucose, bromide 82.

SOME FACTORS AFFECTING THE EFFICIENCY OF HIGH-RATE BIOLOGICAL FILTERS

Water Pollution Research Lab., Stevenage (England)
A.M. Bruce
Fifth Internation Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

Observations have been made over a 12 month period of the performances of six pilot scale biological filters containing different types of media. When receiving settled domestic sewage at a rate of 6 m cu/day the BOD removal efficiency of filters containing plastic sheet packings for mineral aggregate medium was related in a fairly consistant manner to the specific surface area provided by the medium. A tubular plastic medium demonstrated a lower efficiency than the other media in relation to the specific surface provided. The effect of temperature on performance was pronounced and the calculated value of the temperature coefficient was much greater than that which has been found in studies elsewhere. In analyzing the seasonal effects due to temperature changes the temperature coefficent C was found to range between 1.1 and 1.035 with a mean 1.21. This value was substantially greater than the value 1.035 normally applied to lightly loaded percolating filters. The temperature range of this study was between 18 deg C to 9 deg C which caused a fivefold change in oxygen uptake or substrate utilization.

Keywords: trickling filter, films, surfaces, materials, biological treatment, filtration, biochemical oxygen demand, pilot plants, and sewage treatment.

DEVELOPMENTS IN BIOLOGICAL FILTRATION

Cornell Univ., Ithaca, N.Y.
(Editors: E. F. Gloyna and W. W. Eckenfelder, Jr.)
Austin, Texas, University of Texas Press, pages 204—214 (1968)

A review is made of the major empirical and mathematical formulations for single-stage filters and recirculating filters and to define the process action of trickling filtration. Recirculation is an established fact with the operation of high rate trickling filters, affording uniformity and equalization of loadings, flexibility of plant operation, and beneficial seeding effects on plant influent. Some new concepts are presented concerning certain major factors which affect the performance of a biological treatment system. A continuous flow system includes some reactor (i.e., an activated sludge, a trickling filter or a sedimentation basin process) which has the function of reducing some undesirable property associated with the flow. The efficiency of such a system depends mainly on: (1) the type flow pattern of material passing through the system and (2) the kinetics of the reaction itself. The effects of plug flow and completely mixed flow patterns on the efficiency of a system undergoing a first-order treatment reaction are described. The importance of bacterial concentration in most biological treatment systems regardless of the type of flow pattern is emphasized. Practical observations are made on the relationships of flow to bacterial concentration in determining the efficiency of trickling filter systems.

Keywords: biological, treatment, filtration, mathematical studies, trickling filters, mathematical models, biochemical oxygen demand, filters, waste treatment, flow characteristics, design, biological filtration, empirical models, recirculation filters, reaction kinetics, flow patterns, high-rate trickling filters, mass transfer coefficients, system design, plug flow and mixed flow.

TRICKLING FILTER MODEL: DESIGN AND COST FACTORS

Robert A. Taft Water Research Center, Cincinnati, Ohio
J.F. Roesler and R. Smith
Industrial Water Engineering, Vol. 6, No. 9, pages 46—49 (Sept 1969)

A mathematical model of a trickling filter and final settling process was described in the study. The model constituted a single subroutine in a computer program involving the preliminary design of wastewater treatment systems. The subroutine specifically computed the relationship of the various physical properties of the trickling filter, BOD removal efficiencies, and costs. The latter included capital, operating and maintenance costs for the trickling filter, final settler and return pumps. The costs to remove BOD were plotted against the hydraulic loading. For filter depths of 6 and 20 feet, minumum costs were observed near hydraulic loadings of 10 and 20 mgd per acre, respectively. Plots of total costs rather than costs per BOD removed indicated that the greater the specific area, the lower the costs.

Keywords: trickling filters, mathematical models, design, cost allocation, biochemical oxygen demand, waste water treatment, efficiencies, capital costs, operation and maintenance and computers.

APPLICATION OF THE CONTINUOUS CULTURE THEORY TO THE TRICKLING FILTER PROCESS

Georgia Inst. of Tech., Atlanta
B.H. Kornegay and J.F. Andrews
Proceedings, Industrial Waste Conference, 24th, pages 1398—1425 (May 6, 7 and 8, 1969)

The need for a rational approach to trickling filter design is apparent from a review of the literature. It has been shown that existing design equations provide filter volumes that vary by a factor of more than ten when designed for the same effluent quality. A mathematical model of a trickling filter has been developed based on the known facts and the assumptions that: (1) plug-flow is achieved in the liquid phase; (2) substrate utilization by microorganisms in suspension is neglible; (3) the apparent yield remains constant with depth; and, (4) removal is described by a saturation functions.

Keywords: waste water treatment, trickling filters, mathematical models, design, kinetics, plug flow, reactors in series.

ORGANIC AND LIQUID RETENTION TIME IN A TRICKLING FILTER FORMULATION

M.I. Sheikh
Proc. 5th int. Conf. Wat. Pollut. Res., 1, Pap. No. II-13. 8 pages (1970, 1971)

Liquid and organic retention periods were studied in percolating filters (see also Wat. Pollut. Abstr., 1966, 39, Abstr. No. 2142) and the results were used to derive a relation between the two parameters which could be used to compute the filter efficiency and to assist in the design of filters.

Keywords: trickling filter, organics, hydraulic and retention time performance.

KINETICS OF FIXED-FILM BIOLOGICAL REACTORS

B.H. Kornegay and J.F. Andrews
Proc. 22nd, ind. Waste Conf. Purdue Univ., Engng Entn Ser. No. 129, pages 620—630 (1967)

A mathematical model was developed to describe the kinetics of fixed-film biological reactors, based on application of the theory of continuous culture of microorganisms, and the theory was tested experimentally. As expected, it was found that the thickness of the microbial film varied during a transition period of film accumulation but eventually reached a constant thickness. Uptake of both dissolved oxygen and substrate reached a steady-state value after the film reached a thickness of 70 μ, and there was no increase in rate of removal with further increase in film thickness. The advantages of applying the continuous-culture theory to the design and operation of percolating filters are indicated; a continuous function is obtained which describes the rate of substrate removal from zero-order at high concentrations to first-order at low concentrations.

Keywords: kinetics, biological trickling filter, design and operation.

THE EFFECTS OF RECIRCULATION ON THE PERFORMANCE OF TRICKLING FILTER MODELS

Rice Univ., Houstin, Tex.
G.J. Kehrberger and A.W. Busch
Proceedings, Industrial Waste Conference, 24th, pages 37—52 (May 6-9, 1969)

A theoretical analysis of the effect of recirculation of trickling filter effluent on removal of total organic carbon was conducted. The general heterogeneous, reaction control, and pseudo homogeneous models were considered. Development and solution of the mathematical models are not discussed. For heterogeneous film flow reactors, recirculation was found to have a definite detrimental effect on total soluble organic carbon removal. For pseudo homogeneous film flow reactors, the exact opposite effect was observed. The possible accumulation of organic intermediates in the heterogeneous reactors was also indicated. Removal of organics, passed thru as intermediates, can be accomplished but it required use of a separate stirred reactor with a mixed biological population. Therefore, recirculation was shown to be completely unamenable to universal declarations of beneficial or detrimental without prior knowledge of the operating system and conditions.

Keywords: trickling filters, biodegradation, flow rates, waste dilution, microorganisms, organic loading, solubility, diffusivity, dissolved oxygen, aerobic conditions, anaerobic conditions, nutrients, nitrates, waste water treatment, filtration, model sutdies, fixed film biological reactors and recirculation.

DEMONSTRATE FEASIBILITY OF THE USE OF ULTRASONIC FILTRATION IN TREATING THE OVERFLOWS FROM COMBINED AND/OR STORM SEWERS

Acoustica Associates, Inc., Los Angeles, Calif.
Available from the National Technical Information Service as PB-201 745, $3.00 in paper copy, $0.95 in microfiche. Final Report (Sept. 22, 1969)

The feasibility, both economic and technical, of using ultrasonic filtration as an aid to removing suspended impurities was investigated. Inputs to the test apparatus included drinking water, simulated sewage, primary and secondary sewage effluents, algae pond effluent, coarsely screened raw sewage diluted 2:1, 5:1, and 10:1 with simulated storm drainage, and deliverately concentrated raw sewage. Dirt, sand, and leaves were added in some test runs, with no apparent effect on performance. Twenty and 50 micron filter elements, operated at approximately 10 gpm/ft2 with head losses from 1 to 4 psi, reduced the BOD and suspended solids of raw sewage, diluted in varying degrees with water by an average of 40 and 70%, respectively. System performance was intermediate between that of primary and secondary treatment. Other benefits included: 1) the application of ultrasonic energy increased the total quantity of effluent filtered between backwash cycles from 4 to 18 times that treated with similar equipment without ultrasonics applied, and 2) the application of ultrasonic energy restored the filter elements to "like-new" condition, without necessitating frequent filter replacement. Cost figures for an ultrasonic filtration system capable of handling 1.4 mgd, exhibiting a performance midway between primary and secondary treatment, and occupying only several hundred square feet, ranged between 2.8 and 3.5 cents/1000 gallons. By comparison, combined primary-secondary treatment cost figures were reported as 10 cents/1000 gallons, excluding the cost of the considerable amount of land involved.

Keywords: ultrasonics, suspended load, filtration, algae, colloids, flocculation, mixing, economic feasibility, technical feasibility, cost analysis, sludge, incineration, sedimentation, biochemical oxygen demand, wastewater treatment, overflow, sewers, storm drains, sewage effluents, sewage treatment, storm runoff, backwashing, suspended solids, combined sewers, and stormwater overflows.

DISPATCHING SYSTEM FOR CONTROL OF COMBINED SEWER LOSSES

Callery, R. L.
Minneapolis-St. Paul Sanitary District (now the Metropolitan Sewer Board), St. Paul, Minnesota
EPA, Demonstration Grant 11020 FAQ (March 1971)

Impressive reductions in combined sewer overflow pollution of the Mississippi River in Minneapolis and St. Paul have been effected by a regulator control system. Working entirely within the limits of the existing interceptor sewer system, and with relatively minor modifications to selected major combined sewer regulators, the incidence of overflow was reduced by 66% and the duration of overflow by 88% during most of a rainfall season. Computer simulation techniques (using actual rainfall data) indicate that the amount of overflow volume reduction achieved is the equivalent of a $200 million separation project. The efficiency of collection was improved by about 20% at controlled regulators. The reduction in volume of combined overflow to the river is estimated to be between 35% and 70% during the runoff season. The unmodified combined sewer system captured about 65% of the urban runoff. Where modified, the system captured about 77% of the urban runoff. A mathematical model has been prepared that will, with rain gage data as input, perform rainfall runoff analysis, diversion of combined sewer runoff hydrographs at regulators, and routing of diverted hydrographs through the interceptor system. This model will assist in operation of the system to retain combined sewer flows and utilize the maximum flow capacity of the existing interceptor sewer system. Part II of this report describes the model. The $1.75 million project includes a computer-based data acquisition and control system that permits remote control of modified combined sewage regulators. Data from rain gages, regulator control devices, trunk sewers and interceptors, and river quality monitors provide real-time operating information. Time varient quality data from key locations in the sewer system were obtained by an automated analysis of numerous hourly samples. Work on the dispatching system for control of combined sewer losses began in 1966, and the system has been operated since April 1969.

Keywords: overflow, computer, regulators, control, urban runoff, model, rainfall, hydrographs, and interceptor.

DEEP TUNNELS IN HARD ROCK

Bacon, V.W. and Seaburg, T.A.

College of Applied Science and Engineering, University of Wisconsin; Milwaukee and University Extension, University of Wisconsin, Civic Center Campus, Milwaukee, Wis. (Nov. 9—10, 1970)

The proceedings that follow contain information presented at the Civic Center campus of the University of Wisconsin in Milwaukee on November 9—10, 1970. The program was conducted by the University Extension under the technical guidance of the College of Applied Science and Engineering. Arrangements for the program and compilation of these proceedings were completed under the supervision of Professors V.W. Bacon and P.A. Seaburg. The proceedings are published by the Office of Research and Monitoring of the EPA.

Keywords: storage, stormwater, economics, pumping, tunneling, mechanical modes, geology, and excavation.

CONTROL OF INFILTRATION AND INFLOW INTO SEWER SYSTEM

American Public Works Association
EPA, Contract No. 14-12-550, Project No. 11022 EFF (Dec. 1970)

Two hundred and twelve public jurisdictions in the United States and Canada were contacted, and 26 communities were visited. The practices of consulting engineers and state and provincial water pollution control agencies were also surveyed. These surveys indicated that infiltration and inflow are widespread problems. The reduction of infiltration should be stressed in both new and old systems. For new sewers, a construction allowance of no more than 200 gpd per inch of diameter per mile of pipe is recommended. Existing systems must be extensively investigated to determine the extent and location of infiltration. The reduction of inflow waters can be accomplished after sources of such flows have been identified, alternate methods of disposal identified, and the backing of public and governing bodies secured. Twenty recommendations are given, indicating the need for extensive investigation of the extent of the infiltration/inflow problem before relief sewers are constructed or wastewater treatment plants built or enlarged. The report includes 43 tables, an extensive review of reports concerning local infiltration studies, and a bibliography of 135 references.

Keywords: infiltration, inflow, investigation, inspection, and survey.

CHEMICAL TREATMENT OF COMBINED SEWER OVERFLOWS

The Dow Chemical Company, Midland, Mich.
EPA, Contract No. 14-12-9, Project No. 11023 FDB (Sept. 1970)

Overflows of sanitary sewage with stormwater contribute to the population and deterioration of water resources. The description of a typical pumping station, the characteristics of combined sewage overflows, and chemical treatment of overflow with chemical flocculants and disinfectants are included herein. Combined sewage from a residential community of 3990 acres in northeast Detroit, Michigan, is collected at the Milk River Pumping Station. During 8 years of recordkeeping, overflow rates did not exceed 410 cfs (184,000 gpm) for 90% of the pumping time. Overflow volumes did not exceed 5.5 million cubic feet (41.1 million gallons) for 90% of the occurrences. The average number of days of pumping per year (41) is about equal to the average number of days per year having precipitation of 0.2 inches (45). Twenty-two analyses were performed on consecutive time-weighted samples of influent and effluent during 33 storms over a 2-year period. Biochemical oxygen demand and suspended solids decreased after initial flushing of the sewers. Chlorine demand values remained relatively constant throughout storms. The Milk River channel and the immediate receiving bay were severely polluted. Cationic polymeric flocculants and flocculant aids significantly improved the removal of suspended solids from combined sewage, as demonstrated by tests in beakers and a long-tube sedimentation column. Adequate disinfection of the combined sewage before discharge to the channel is possible. The performance of the existing basin can be improved by the use of staged continuous pumping at lower rates and the addition of baffles for improved flow distribution.

Keywords: **combined sewerage, stormwater, chemical treatment, overflow, flocculants, flow distribution, improved performance, and disinfection.**

HYPOCHLORITE GENERATOR FOR TREATMENT OF COMBINED SEWER OVERFLOWS

Ionics, Inc., 65 Grove St., Watertown, Mass.
F.D. Leitz, S.A. Michaelek, and J.L. Greatorex
EPA, Contract No. 14-12-490, Project No. 11023 DAA (March 1972)

hypochlorite for disinfection of overflows from combined sewer systems. In this system an electrochemical cell electrolyzes sodium chloride brine to chlorine gas and sodium hydroxide solution, which are reacted immediately outside the cell to produce a 5 to 10% sodium hypochlorite solution. Significant advances in safety and economy have been realized by use of a hydraulically impermeable cation exchange membrane. The most critical components, the dimensionally stable anode and the ion-exchange membrane, have both operated for over 3000 hours with no deterioration of performance. System operation has been given a first-order economic optimization. At a current density of 240 asf, the cell potential is 3.7 volts. The generator requires 1.6 kwh of electricity and 2.1 pounds of salt per pound of sodium hypochlorite. Salt utilization is over 80%. The operating cost for systems larger than 500 pounds of hypochlorite per day is projected to be 3 to 4 cents per pound of hypochlorite. This cost is significantly below that of truck-delivered solution. Such economy of operation should make the generator useful for a wide variety of water treatment applications. The first field unit is scheduled for installation in the northeast Sanitary District in Somerville, Massachusetts, under Grant No. 11023 DME. The estimated operating and maintenance cost is estimated to be 3.7 cents per pound of chlorine or 0.13 cents per thousand gallons of overflow.

Keywords: hypochlorite, on-site generation, electrolytic, ion-exchange membrane, cost reduction, and demonstration.

MAXIMIZING STORAGE IN COMBINED SEWER SYSTEMS

Municipality of Metropolitan Seattle, 410 West Harrison St., Seattle, Wash.
C. T. Leiser
EPA, Contract No. 13-Wash-1, Project No. 11022 ELK (Dec. 1971)

Since the first metropolitan Seattle sewers were constructed, combined wastewater has been discharged into saltwater or estuaries along the Seattle waterfront. Beginning in 1958, plans were developed to make use of storage available in the collection system before combined sewage overflows occurred. The initial plans included: 1) the interception and treatment of raw sewage flowing to saltwater points, 2) the regulation of lines, and 3) the construction of temporary storage tanks at fresh water overflow points. In 1968, a $70 million sewer separation project was approved to increase system storage by reducing storm inflow. Metro funds originally earmarked for storage tanks have been applied to this separation project. All required construction has been completed in a project to demonstrate the feasibility of applying computer control concepts to make maximum use of all available storage within a collection system. Automatic and manual sampling programs are monitoring overflows and adjacent waters. Background data, which has been accumulated and analyzed to establish control conditions before computer activation, show dramatic improvements in receiving water quality resulting from interception and treatment phases of construction. An analysis of monitoring data projects a 50% to 70% reduction in pollutant loading to fresh water after sewer separation projects have been finished. Overflow volume, frequency, and quality factors are monitored to serve as a basis for measuring the performance of the control system as it leaves the instrumented local control phase and begins the totally computer-managed phase.

Keywords: in-line storage, computer controlled, maximum storage, and reduction of pollution load.

SCREENING/FLOTATION TREATMENT OF COMBINED SEWER OVERFLOWS

The Ecology Division, Rex Chainbelt, Inc., Milwaukee, Wis.
D.G. Mason and N.K. Gupta
EPA, Contract No. 14-12-40, Project No. 11020 FDC (Jan. 1972)

This report documents a study to develop a treatment system for combined sewer overflows. The processes of chemical oxidation, screening, dissolved air flotation, and disinfection were evaluated in the laboratory. It was determined that chemical oxidation was not feasible. The majority of the pollutants were of a particulate nature, which indicated that solids/liquid separation processes could possibly provide effective treatment. A 5 mgd combination screening and dissolved air flotation demonstration system was designed, installed, and evaluated. The system was utilized to treat 55 combined sewer overflows. The drainage area served by the facility was a completely developed 500-acre residential area of Milwaukee, Wisconsin. Suspended solids and volatile suspended solids removal in the range of 65—80% were consistently obtained at influent concentrations of 150 to 600 mg/l. BOD and COD removals were slightly lower at 55 to 65% for influent concentrations of 50 to 500 mg/l. The addition of chemical flocculents (ferric chloride and a cationic polyelectrolyte) was necessary to obtain these removals. Without the use of chemical flocculents, the removal of BOD, COD, suspended solids were all in the range of 40 to 50%. The screening/flotation system provided sufficient detention time (15 minutes) for adequate disinfection with hypochlorite salts. Cost estimates indicate a capital cost of $21,056 per mgd capacity of $3828 per acre for a 90 mgd screening/flotation system. Operating costs were estimated at 3.09 cents per 1000 gallons of treated overflow, including a chemical flocculent addition.

Keywords: stormwater, combined sewer overflow, dissolved air flotation, disinfection, flocculents, and liquid-solid separation.

MICROSTRAINING AND DISINFECTION OF COMBINED SEWER OVERFLOWS

Cochrane Division, Crane Co., King of Prussia, Pa.
G. E. Glover and P. F. Yatsuk
EPA, Contract No. 14-12-136, Project No. 11023 EVO (June 1970)

Microstraining, using a microstrainer screen of a nominal aperture size of 23 microns, removes up to 98% of the suspended solids from a combined sewer overflow. The sewer, which has an average sanitary sewage flow of 1000 gph, serves a residential area of 11 acres in the city of Philadelphia. The maximum combined sewer flow recorded during rainstorms in 1 year of operation has been 11.3 cfs (304,000 gph). Volatile suspended solids removals with the 23-micron microstrainer screen have averaged 68% and 71% during different test periods. BOD removals and coliform bacteria concentrations in the microstrained effluents have varied widely. Postulations as to the effects of microstraining on both actual concentrations and measurement techniques are given. The results to date indicate that there is a slightly better kill of coliform group bacteria with chlorine than with ozone in the microstrainer effluents when both are used at an initial nominal concentration of 5 ppm, with 5 to 12 minutes detention time. However, chlorine has been applied at slightly higher levels and with better control than the ozone, and it has not been possible to optimize requirements for these chemical feeds. Limited tests indicate that high dosages of chorine for shorter contact times may be the most efficient and economical approach. Preliminary estimates of the treatment costs for a combined sewer via the microstraining process, using tentatively established microstrainer throughput rates, show that the capital costs per acre of drainage for a full-scale plant in a similar area would be approximately $10,200 for microstraining alone, $11,200 for microstraining plus chlorination, and $19,800 for microstraining plus ozonation. The first two cost figures compare favorably with other techniques that have been proposed. For example, the costs associated with the construction of separate storm and sanitary sewers have, in several cases, been estimated to range between $20,000 and $23,000 per acre. Of eight other currently proposed schemes, whose costs are roughly estimated, only surface impoundment (where it is aesthetically acceptable and where low-cost land is available) appears competitive.

Keywords: screening, suspended solids, coliform bacteria, costs, chlorination, and ozonation.

COMBINED SEWER REGULATION AND MANAGEMENT: A MANUAL OF PRACTICE

American Public Works Association
EPA, Contract No. 14-12-456, Project No. 11022 DMU (July 1970)

Design application, operation, and maintenance of combined sewer overflow regulator facilities are detailed in this Manual of Practice, developed in conjunction with a report prepared on combined sewer overflow regulators. Design calculations are given for various types of regulators and tide gates. A sample regulator facility control program is included to illustrate the development of a control system. Operation and maintenance guidelines are also given. Thirty-eight sketches and photographs are included.

Keywords: combined sewers, design, operation, regulators, tide gates, and maintenance.

PROPOSED COMBINED SEWER CONTROL BY ELECTRODE POTENTIAL

Merrimack College, North Andover, Mass.
Available from NTIS as PB-195 169, $3.00 in paper copy $0.95 in microfiche. Water Pollution Control Research Series 11024 DOK 02/70, (Feb. 1970)

The effectiveness was investigated of electrode potential measurements to modulate discharges from combined and storm sewer overflows to reduce stream and estuarine pollution. Studies included varying the composition of sewage, flow rate, and examining the tendency to polarize or coat the electrodes under actual flow conditions. The analysis of experimental results shows a high degree of correlation between the electrode potential of the sewage and its strength. Linear correlation coefficients between electrode potential were determined for BOD, COD, sulfides, total phosphorus, nitrates and chlorides. It was demonstrated that the potential will be more negative the greater the S—concentration, except when a small amount of DO is present that exerts an attenuating influence. Flows carrying substantial concentrations of reducing substances with a detrimental impact on the dissolved oxygen reservoir of any receiving waters must be kept from exerting their damaging influence on bathing beaches, tidal estuaries, and other water resources. Controlling the flow from outfalls by the electrode potential should significantly help to minimize such insults to the environment.

Keywords: electrodes, flow control, flow rates, sewage, outlets, water pollution control, overflow, dissolved oxygen, pollution abatement, storm runoff, combined sewers, electrode potential, sewage overflows and sewer outfalls.

STORM-WATER RETENTION CAN WORK

Detroit Metro Water Department, Mich.
G. Ramus
The American City, Vol. 85, No. 10, pages 68 and 69 (Oct. 1970)

The city of Detroit, Michigan, has developed a $2.1 million system to assist in collecting data to control discharges from the combined municipal sewer system into the Rouge and Detroit Rivers due to stormwater runoff. The system consists of rainfall gages positioned throughout the city and along the incoming storm path to provide an estimate of the intensity of rainfall, sewer level gages at key points in the sewer system to monitor the ability of the sewer system to absorb runoff, communications, and a computer. Information from the sensors is supplied to a central control center over leased telephone lines, where it is converted from analog data to digital information and printed onto IBM punch cards. At the present time, control operators read the cards and act on the information to anticipate overflow situations, to selectively retain sewage in the system for later treatment, or to selectively discharge sewage into the rivers. The use of this information and control system over the past year has enabled the city staff to learn more about the relationships between rainfall, sewage levels, and overflows to the rivers and it has provided for a reduction in the number and volume of overflows. Future plans call for the inclusion of a digital computer in the system to aid in decision-making.

Keywords: wastewater treatment, sewers, storm drains, flow control, rain gages, flow measurement, data collection, decision-making, scheduling, overflow, retention, Michigan, treatment facilities, water conveyance, combined sewers, and Detroit (Michigan).

COMBINED SEWER OVERFLOW ABATEMENT ALTERNATIVES, WASHINGTON, D.C.

Roy F. Weston, Inc. (Environmental Scientists and Engineers), West Chester, Pa.
P. L. Buckingham, C. S. Shih, J. G. Ryan, J. A. Lee, and J. K. Kane
EPA, Contract No. 14-12-403, Project No. 11024 EXF (Aug. 1970)

Objectives of this project were to: 1) define the characteristics of urban runoff, 2) investigate the feasibility of high-rate filtration for treatment of combined sewer overflow, and 3) develop and evaluate alternative methods of solution. Investigative activities included the review of pertinent reports and technical literature, field monitoring of combined sewer overflows and separated stormwater discharges at three sites, laboratory studies of ultra-high-rate filtration of combined sewer overflow, hydrological analysis, and the evaluation of feasible alternatives (based on conceptual designs, preliminary cost estimates, and other factors). Reservoir storage, treatment at overflow points, conveyance tunnels and mined storage, and sewer separation were the approaches considered sufficiently promising for detailed evaluation. Tunnels and mined storage with treatment at the Blue Plains plant and at Kingman Lake after subsidence of a storm is recommended. Estimated capital costs (based on a 15-year, 24-hour storm) are \$318 million (ENR=1800), with annual operation and maintenance costs of \$3,500,000. This approach also was preferable to others on the basis of systematic evaluation of reliability, flexibility, public convenience and other nonquantifiable factors.

Keywords: combined sewers, stormwater, urban runoff characteristics, high-rate filtration, and cost.

HIGH RATE FILTRATION OF COMBINED SEWER OVERFLOWS

Hydrotechnic Corp. (Consulting Engineers), New York, N.Y.
R. Nebolsine, P.J. Harvey, and C.Y. Fan
EPA, Contract No. 14-12-858, Project No. 11023 EYI (April 1972)

Pilot plant studies were conducted at Cleveland's Southerly Wastewater Treatment Plant in 1970 and 1971 to develop and demonstrate the capabilities of the deep-bed dual-media high-rate filtrate treatment process for storm-caused combined sewer overflows. The treatment system is comprised of a drum screen with a 40-mesh screening element (420 microns opening), followed by a deep-bed dual-media high-rate filter of 5 feet of No. 3 Anthracite (effective size 4 mm) over 3 feet of No. 612 sand (effective size 2 mm). The results show suspended solids removals of 93% with a polyelectrolyte addition at a filtration rate of 24 gpm/sq ft at an average influent suspended solids of 411 mg/l. Reductions in biochemical oxygen demand averaged 65%. Capital costs (ENR=1470) for a high-rate filtration plant are about $23,000 per mgd. Total annual treatment costs, including capital and operating charges, range from approximately $90,000 per year for a 25-mgd plant to approximately $390,000 for a 200-mgd treatment facility. The principal advantages of the proposed system are high treatment efficiencies, automated operation, and limited space requirements, as compared with alternate flotation or sedimentation systems.

Keywords: stormwater, combined sewers, liquid-solid separation, suspended solids, polyelectrolyte, and cost.

RETENTION BASIN CONTROL OF COMBINED SEWER OVERFLOWS

Springfield Sanitary District, Springfield, Ill.
EPA Grant No. 3-111-1 (Aug. 1970)

Control of combined sewer overflows by retention in an open basin has been evaluated. Fish kills, which were numerous prior to construction of the facility, ceased and there was an increase in the abundance of pollution-sensitive organisms in the stream below the basin. The average annual reduction of BOD was 27%, and coliform reduction averaged 72%. However, during the period from June through October 1969, production of algae in the basin caused the effluent BOD to consistently exceed that of the influent. In addition to the oxygen demand on the stream, production of algae may be objectionable at some installations for aesthetic reasons. Sludge accumulation was significant in the basin and must be taken into account in the design of similar facilities. Suggestions for future designs of retention basins are included.

Keywords: combined sewers, urban drainage, retention basins, lagoons, and combined sewer overflow.

SELECTED URBAN STORM WATER RUNOFF ABSTRACTS (JULY 1970—JUNE 1971)

Science Information Services Department, the Franklin Institute Lab.
EPA, Contract No. 14-12-904, Project No. 11024 FJE (July 1971)

The July 1970—June 1971 supplement to Selected Urban Storm Water Runoff Abstracts is a compilation of abstracts summarizing articles from a variety of technical literature concerning the problem of urban drainage, published from July 1970 through June 1971. The 234 abstracts, covering a range of 10 sections, are arranged alphabetically by author and numerically by abstract number within each category. Each item includes a bibliographic citation, an abstract, and a set of indexing descriptors and identifiers. A subject index at the end of the volume provides the necessary access to individual concepts. An author index and a journal list are also included.

Keywords: literature search, abstracts, stormwater, and urban drainage.

[illegible] Neketin T.H. and Dennis, H.K. Jr.

DEMONSTRATION OF ROTARY SCREENING FOR COMBINED SEWER OVERFLOWS

Portland Department of Public Works, Oregon Bureau of Sanitary Engineering
T.H. Neketim and H.K. Dennis, Jr.

Available from GPO Supervisor of Documents, $0.65; Microfiche from NTIS as PB-206 814, $0.95
EPA, Research and Montoring, Water Pollution Control Research Series (July 1971)

A 60-inch-diameter rotating screen cage was subjected to various combinations of rotational speeds and wastewater flows to determine screen durability, solids removal, COD removal, and the hydraulic efficiency of rotary fine screening of storm-caused combined sewer overflows. During a screening cycle, a concentrate sensor stopped the sewage pumps, ending the screening phase and initiating a 30-second washing phase during which the screens were automatically washed. At the end of the cleaning phase, the pumps restarted automatically and a new cycle began. Such screening effected 54.8% settleable solids removal, 26.6% suspended solids removal, and 15.5% COD removal on the average. Screening phase duration averaged 14.6 minutes, with average hydraulic efficiencies dropping from 0.880 to 0.668. Ultimate screen life varied from a minimum of 190.5 hours to a maximum of 516 hours, with an average of 346. Screens required an average of 3.5 repairs during screen life. Alkaline, acidic, and alcoholic agents did not adequately clean the screens, while chloroform, solvent parts cleaner, soluble pine oil, Zip, Formula 409, and Vestal Eight offered only limited effectiveness. Zep 9658 cleaned the screens effectively, but water quality implications were not determined. Screen rpm in excess of 55 and sewage flows in excess of 3.0 mgd proved disastrous to screen life, and final testing was conducted under these conditions.

Keywords: storm runoff, screens, filtration, operation and maintenance, automatic control, efficiencies, water quality control, wastewater treatment, chemical oxygen demand, overflow, sewers, rotary screening, combined sewer overflows, suspended solids, backwashing, and cleaning.

ROTARY VIBRATORY FINE SCREENING OF COMBINED SEWER OVERFLOWS

Cornell, Howland, Hayes, and Merryfield (Consulting Engineers and Planners), Corvallis, Oregon
EPA, R&D Project No. 11023 FDD (March 1970)

The objective of this study was to determine the feasibility, effectiveness, and economics of employing high-rate fine-mesh screening for primary treatment of stormwater overflow from combined sewer systems. The final form of the screening unit stands 63 inches high and has an outside diameter of 80 inches. The unit is fed by an 8-inch pipe carrying 1700 gpm (122 gal/min/ft^2), which is distributed to a 60-inch-diameter rotating (60 rpm) stainless steel collar screen having 14 square feet of available screen area and a 165 mesh (105-micron opening, 47.1% open area). The screen is backwashed at the rate of 0.235 gallons of backwash water per 1000 gallons of applied sewage. Based on final performance tests run on dry weather sewage, the unit is capable of 99% removal of floatable and settleable solids, 34% removal of total suspended solids, and 27% of the influent flow. On the basis of a scale-up design of a 25 mgd screening facility, the estimated cost of treatment is 22 cents/1000 gallons. No finite cost comparisons were made with other treatment methods; however, when compared to conventional primary sedimentation, the selection of a screening facility as a treatment method depends on the value and availability of land, the design capacity of the treatment facility, the character of rainfall and runoff, and the available means of disinfection. It was observed that the proposed screening facility required 1/10 to 1/20 the land required by a conventional primary treatment plant.

Keywords: screening, high rate, feasibility, effectiveness, economics, and suspended solids.

MANAGEMENT AND CONTROL OF COMBINED SEWER OVERFLOWS

R. Field and E.J. Struzeski, Jr.
Journal Water Pollution Control Fed., 44, 1389 (1972)

Combined sewers are a source of water pollution problems, but even flows of stormwater alone can seriously affect water quality. Sewer separation is very costly and solves only about 50% of the problem. Current approaches involve control of combined overflows, treatment, and combinations of the two. Control can involve the maximizing of treatment with existing facilities, improvement of regulator maintenance, control of infiltration and extraneous inflows, surface sanitation, and addition of flow-increasing polymers, as well as flow regulation and storage, use of porous pavement, and vacuum and pressure-type sewer systems. A number of treatment methods are being evaluated. Among the most promising are microstraining at high rates, ultra-high-rate filtration on various media, screening and dissolved-air flotation, and the rotating biological contactor. Disinfection processes can also be adapted to storm flows.

Keywords: combined sewers, control, filtration, overflows, storage, stormwater, and wastewater treatment.

COSTS

COSTS

With the increasing demand for higher effluent quality, wastewater treatment plant construction requires substantial amounts of capital. Moreover, the operation and maintenance of these plants are expensive. The major operating costs include (in order of importance) labor, utilities, and chemicals. Automatic control systems can reduce the operating expenses of wastewater treatment facilities through savings of operational labor, energy consumption, and chemical usage. Occasionally, automatic control increases performance to the extent that capital savings are possible through smaller treatment structures.

As the demand for more intensive treatment continues, wastewater treatment plants will start to resemble chemical works. Most chemical companies invest about 10 percent of a plant's cost in instrumentation and automatic control; currently, municipal facilities devote only 1 percent of their capital cost to instruments and automatic control devices. Process control traditionally reduces operating costs at the expense of increased capital costs. Intuitively, in small plants, control system costs outweigh reductions in operation expenses; for large plants, these savings justify the installation of control systems. Clearly, economic factors will determine the type and amount of instrumentation and automatic equipment installed in wastewater treatment plants. If the payback period for automatic control devices is within the 3-year range, then the employment of such devices can be economically justified.

This cost literature search is a collection of abstracts highlighting economic articles related to the capital, operating, and maintenance costs of wastewater treatment facilities. The search covered most leading environmental, instrumentation, and automatic control periodicals published from 1969 to 1973.

The forthcoming criteria directed the choice of economic articles collected during this search:

- Sources of cost estimates for the construction, operation, and maintenance of wastewater treatment facilities as a function of capacity, size, or performance
- Costs of individual pieces of equipment
- Articles demonstrating the cost benefits of automatic control.

Because the degree and type of instrumentation and automatic control devices must be economically justified, the major goal of this literature search is to provide the input data for amortization economic balances that leads to calculations of payback periods.

COST OF PROCESS INSTRUMENTS, PART 1

B.G. Liptak
Chemical Engineering, Vol. 77,19, pages 60—76 (Sept. 1970)

Because of the lack of pricing data, estimating the instrumentation costs for a new process or proposed plant has been difficult. The author presents instrument cost data in easy-to-use tabular or graphic form. These data, which can be used for estimating the cost of either control components or entire systems, are based on 1969 prices and the quantity of instruments needed for a chemical plant in the $1 to $5 million total cost range. Correction factors are supplied to update the pricing data and also to reflect quantity discounts. The total cost of instrumentation includes instrument materials (primary elements), installation labor, design engineering, and installation materials. Instrument costs can be estimated by one of three methods. The easiest but least accurate technique employs a percentage of total plant costs. A more accurate approach is to relate instrument expenses to total plant equipment costs. The most reliable method, however, involves preparing a detailed instrument list and pricing the instruments individually. Information is given for all three techniques for determining the instrument material costs. Regardless of the method used to determine the instrument material costs, the installation labor and material costs are detailed as a percentage of the instrument material costs. The percentage depends upon whether the plant utilizes local or central control and pneumatic or electronic instruments. Installation material costs range from 9% to 12% of the instrument material costs; installation labor costs vary from 35% to 52% of the instrument material costs. Engineering and design manhour requirements are included for efficiently, normally, and poorly managed projects as a function of instrument material costs. A typical instrumentation expense breakdown at the time of plant startup is as follows: 1) instrument materials—60% 2) installation labor—20% 3) design engineering—15%, and 4) installation materials—5%. Operating costs, defined in the narrow sense of expenses necessary to keep the instrumentation in operation, usually total about 10% per year. Maintenance labor accounts for most of this operating expenditure, and only a small fraction of the operating costs goes to parts replacement. There is a great deal of variance (about ±50%) among the various plants. Part 1 of this four-part series presents detailed cost data on level instruments, pressure detectors, chemical seals, density detectors, temperature detectors, flow elements, and metering pumps.

Keywords: instrumentation, process, price data, operating costs, installation, primary elements, chemical plants, design and engineering, local control, central control, pneumatic, and electronic.

COST OF VISCOSITY, WEIGHT, ANALYTICAL INSTRUMENT, PROCESS INSTRUMENTS, PART 2

B.G. Liptak
Chemical Engineering, Vol. 77, 20, pages 175—179 (Sept. 21, 1970)

Costs for process instruments include data for the primary indicating device, coupled with a suitable transmitter. Price data on many process instruments and their auxiliaries, which measure viscosity, weight, thermal conductivity, oxygen concentration, pH, moisture, and humidity, are presented. Also, cost data are given for turbidity, consistency, molecular weight, and conductivity instruments, as well as for chromatographs and refractometers.

Keywords: process instruments, primary sensors, detectors, transmitters, price data, cost estimates, and intermittent and continuous laboratory instruments.

CONTROL-PANEL COSTS, PROCESS INSTRUMENTS, PART 3

B.G. Liptak
Chemical Engineering, Vol. 77, 21, pages 83—86 (1970)

Control panel cost estimates are based on per-foot cost data for steel and Melamine construction materials. Semigraphic and full graphic displays increase panel expenditures by $125/ft and $250/ft, respectively. Recorder and indicator pricing data is also presented in tabular form. Cost estimating data for associated devices such as controllers, converters, computing relays, and miscellaneous panel instruments are given in a series of tables.

Keywords: control panels, price data, cost estimating, recorders, indicators, process controllers, and converts.

SAFETY INSTRUMENTS AND CONTROL-VALVE COSTS, PROCESS INSTRUMENTS, PART 4

B.G. Liptak
Chemical Engineering, Vol. 77, 24, pages 94—100 (Nov. 2, 1970)

Instrument cost data are presented for pressure relief and explosion suppression devices. These include spring- and weight-loaded valves, rupture disks, and conservation and emergency vents. Price data for flame arrestors, dehydrators, excess flow check valves, and combustible-gas detectors are also delineated through graphs and supporting narrative. Expenditure estimating data for control valves, the most commonly employed final control element, are supplied for globe-type, butterfly, Saunders ball and plug, and characterized ball valves. Valve costs are broken down as functions of size and material of construction.

Keywords: safety instruments, control valves, cost data, price estimating, controllers, and regulators.

ECONOMIC JUSTIFICATION OF COMPUTER CONTROL SYSTEMS

T.M. Stout
Automatica, Vol. 9, pages 9—19 (1973)

Control of an industrial process can be described as making adjustment in certain manipulated variables in order to achieve well-defined objectives in the face of disturbances, using such measurements, control devices, and procedures as may be appropriate technically and justified economically. Where a computer control system is the appropriate solution to a process problem, a choice now exists between packaged systems for standard applications and custom systems to meet special requirements. Computer system costs may vary from $50,000 to as much as $8,000,000. The benefits from computer control are found in the increased production, improved control of product quality, better use of raw materials, reduced operating manpower, and savings in capital investment. Simple examples illustrate the calculation of benefits from better quality control through increased production or reduced operating costs. The best criterion for evaluating a proposed computer control system is the expected return on investment, which allows consideration of the timing of income and expense items as well as their magnitudes. This criterion also focuses attention on the need for effective project management. Published cost and benefit figures are given to show typical results obtained in actual control computer installations.

Keywords: automatic control, costs, benefits, and return on investment.

EQUIPMENT MARKET—WATER AND WASTEWATER

K. L. Kollar and W. G. Youngwirth
Jour. Water Poll. Control Fed., 44, 319 (1972)

Trends in market analysis of water supply and wastewater treatment equipment expenditures are observed from 1965, 1968, and 1970 data; projections to 1980 are made. Decreases have been experienced in all aspects of municipal water supply while equipment and construction expenditures increased sharply for wastewater facilities and are expected to climb steadily to 1980. In the industrial area increases of 75 percent are anticipated in both fields to 1980. Available data are difficult to assess because of the many unknowns in predicting government authorizations, appropriations, release of funds, and, finally, the actual pace of design and construction.

Keywords: construction, construction grants, costs, design, economics, industrial wastes, planning, plants purchasing, wastewater treatment and water.

COST AND MANPOWER FOR MUNICIPAL WASTEWATER TREATMENT PLANT OPERATION AND MAINTENANCE

Federal Water Quality Administration, Washington, D. C. Construction Grants and Engineering Branch
R. L. Michel
Journal Water Pollution Control Federation, Vol. 42, pages 1883—1915 (Nov. 1970)

An analysis was made of the operation and maintenance expenditure and manpower requirements for wastewater treatment works as reported for some 1,600 such audits during the period January 1965 to June 1968. A statistical test (simple linear correlation) was used to determine the trends between the following combinations of variables: (1) Total annual cost vs. average flow rate; (2) Total annual cost vs. population equivalent load; (3) Annual labor cost vs. average flow rate; (4) Annual labor cost vs. population equivalent load; (5) Annual electricity cost vs. average flow rate; (6) Annual electricity cost vs. population equivalent load; (7) Annual chemical cost vs. average flow rate (8) Annual chemical cost vs. population equivalent load; (9) Total weekly man-hours vs. average flow rate; (10) Total weekly man-hours vs. population equivalent load. All the results were plotted on figures. In general, the cost patterns derived from this study were very similar to those derived from the 1,500 reports of a different set of plants audited between 1962 and 1965.

Keywords: costs, wastewater treatment, operation and maintenance, correlation analysis, trickling filters, lagoons, total population equivalent, industrial population equivalent, total weekly man-hours, sludge process and power consumption.

WASTEWATER TREATMENT PLANT CONTROL

EPA, Office of Research and Monitoring, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio
R. Smith

Available from National Technical Information Service, Paperback 213-827. Presented at Joint Automatic Control Conference, Washington University, St. Louis, Mo. (August 11—13, 1971)

Because of the difficulty of assigning a cost penalty to environmental damage caused by poor quality effluent being discharged from a wastewater treatment facility, the author assumes that some level of effluent quality is required and examines the economic impact of instrumentation and automation. After delineating the goals of instrumentation and automation that revolve around increased reliability at decreased cost, several principal control loops for a conventional treatment plant are identified. Based on good operating procedures, a rationale is developed for selecting process control schemes. In tertiary or independent physical chemical treatment, chemical feeding and pH control loops are essential for effective treatment. As examples, phosphorus removal (via mineral addition to the aerator and lime precipitation) and nitrogen removal (via nitrification-denitrification and breakpoint chlorination) are discussed. Since the equipment, structure, manpower, chemical utility, and instrumentation costs are functions of the degree of treatment, the designer and plant manager should use the correct mix to effect satisfactory treatment at minimum cost. From the slope of degree-of-treatment cost charts for BOD_5, SS, COD, phosphorus, and nitrogen, the incremental cost for increased removal can be calculated. In general, the incremental removal cost increases as the residual concentration decreases; the cost for treatment for a specified degree decreases as the plant size increases. With this data the cost factors can be compared to each other, assuming that effluent quality is fixed; thus, certain kinds of instrumentation and automation can be economically justified. To demonstrate the rationale for relating manpower, equipment, structure, and automatic control equipment. the author considers examples of primary sludge pumping control via nuclear density to regulate digester loading, sludge blanket control, DO control, reduced overflow rates for final clarifiers, and oversized sludge return pumps for a 10-mgd activated sludge plant. Based on 1971 cost data for nonsupervisory workers in sanitary systems and a 10-year life expectancy for instruments and control equipment, one manyear is equivalent to $64K invested in instrumentation and control equipment. From recently published studies, water treatment plants spend 5% of construction costs for instruments and automatic control; wastewater treatment plants spend only 1% of construction costs for instruments and automatic control equipment.

EQUIPMENT COSTS

Keywords: wastewater treatment, automation, instruments, process control, economics, manpower, structure sizes, utility costs, and chemical costs.

CONDENSED ONE-PAGE COST ESTIMATES FOR WASTEWATER TREATMENT

R. G. Eilers
EPA, Office of Research and Monitoring, Advanced Waste Treatment Research Laboratory,
Cincinnati, Ohio (Nov. 1970)

Construction cost, amortization cost, operation and maintenance cost, and total treatment cost were calculated for various wastewater treatment processes at volume flows of 1, 7.5, 10 and 100 mgd. The construction and operation and maintenance costs for the primary sedimentation and activated sludge processes were taken from curves in the report, "Cost of Conventional and Advanced Treatment of Wastewaters." The same costs for the other processes (except chlorination) were taken from curves in the report, "Cost and Performance Estimates for Tertiary Wastewater Treating Processes." The costs for chlorination were obtained using curves supplied by Black and Veatch. For the chlorination cost calculations, it was assumed that a 10 mgd plant uses 8 ppm of chlorine 100% of the time (124 tons/year) and has a 14,000 cubic feet contact basin. The costs for the 1, 7.5 and 100 mgd chlorination processes were obtained by scaling the 10 mgd parameters. The costs for single stage lime clarification were obtained using the cost curve for the two stage lime clarification process. Recalcination construction and operation and maintenance costs were the same for both. Single stage construction cost was obtained at half the volume flow for the two stage process. Single stage operation and maintenance cost was taken as half of the cost obtained at half the volume flow for the two stage process. All construction costs were adjusted to January 1970 dollars using the construction cost index; operation and maintenance costs were adjusted to January 1970 dollars using the consumer price index. Amortization costs were calculated based on 25 years at 6% interest. Graphs of construction costs and total treatment costs versus flow for the various processes are described. Ten additional tables of various cost and bond indexes are also provided, so that the cost figures given in this report can be updated.

Keywords: construction, cost, operation and maintenance cost, wastewater treatment, and consumer price index.

COST ESTIMATING GUIDELINES FOR WASTEWATER TREATMENT SYSTEMS

Bechtel Corporation, San Francisco, California
W. F. McMichael
Program No. 17090 DRU, Contract No. 14-12-582, FWQA Project Officer, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio (July 1970)

This manual provides guidelines for the cost estimator concerned with various wastewater treatment systems now under investigation by the Federal Water Quality Administration. Direction is given for the uniform presentation of capital and annual cost data now being developed. Individual sections deal with suggested forms for submitting reports, including an outline, and method and format for preparing capital and annual cost estimates for FWQA studies. The following specific data are appended: (1) summary of cost indices useful in scaling capital costs of previous years to present, (2) description of typical operating cost data; sources of additional data, (3) discussion of municipal bonds and financing and (4) discussion of levels of estimates and expected accuracies.

Keywords: estimated costs, wastewater treatment, annual costs, capital costs, maintenance costs, and operating costs.

ESTIMATING COSTS AND MANPOWER REQUIREMENTS FOR CONVENTIONAL WASTEWATER TREATMENT FACILITIES

W. L. Patterson and R. F. Banker
Black & Veatch, Consulting Engineers, Kansas City, Missouri
EPA, Project No. 17090 DAN, Contract No. 14-12-462 (Oct. 1971)

Data for estimating average construction costs, operation and maintenance costs, and manpower staffing requirements, are presented for conventional wastewater treatment plants ranging from 1 to 100 million gallons per day in capacity, and for stabilization ponds ranging from 0.1 to 10 million gallons per day in capacity. Estimating data are included for 21 separate components of conventional plants and 6 separate components of stabilization ponds. Examples of use of the data are given. Estimated average construction costs and operation and maintenance costs are related graphically to appropriate single parameters for respective plant components. Occupation descriptions for 24 job titles related to wastewater treatment, developed in accordance with standards of the Dictionary of Occupational Titles, are included in the report. The data presented provide means of estimating costs and staffing requirements for a variety of conventional wastewater treatment facilities on an average basis, but do not supplant the need for detailed study of local conditions or recognition of changing design requirements in preparing estimates for specific application.

Keywords: manpower staffing and cost data.

COST OF WASTE WATER TREATMENT PROCESSES

Dorr-Oliver, Inc., Stamford, Conn.
D. DiGregorio
Available from NTIS as PB-187 760, $3.00 in paper copy, $0.95 in microfiche. Federal Water Pollution Control Administration, FWQA Robert A. Taft Water Research Center Report No. TWRC-6, 53 pages (Dec. 1968)

New capital cost information for conventional and some advanced waste water treatment processes has been collected and correlated in terms of capacity and size. Operating costs have been calculated for some of the processes. Conventional processes considered include comminution, grit removal, primary settling, biological treatment of activated sludge and trickling filter, final settling, and sludge treatment and disposal. Advanced processes include phosphate extraction, chemical clarification, and sand filtration, carbon adsorption, and membrane ultrafiltration. An extensive survey of Dorr-Oliver, Inc., sales information yielded a large volume of data relating equipment costs to loading and equipment size. Costs, including profit and installation, were updated by applying factors derived from known equipment price increases. Construction costs, including material, labor, profit, engineer's and contractor's fees, were estimated from company experience and updated. The information provided is concerned only with the unit process under consideration. No effort was made to evaluate the

cost of land, excavation or inter-process requirements. The method of lease squares was used to correlate the generated data. In many cases the data could be described by a straight line. Y—aX..b, on an arithmetic or logarithmic plot. Where this description was not satisfactory, an equation of the form Y—1/aX..b was used. A computer program was written to facilitate the lease square computations.

Keywords: cost, waste water treatment, activated sludge, trickling filters, sludge treatment, sludge disposal, sales, profit, labor, and materials.

ON THE COSTS OF BIOLOGICAL SEWAGE TREATMENT

U. Schmidt
Veroff, Inst. SiedlWassWirt., Hannover, No. 13, 182 pages (1964)

A detailed, statistical survey, including tabulated and graphical data, is given on the costs of various biological sewage-treatment processes in Germany. Calculations were carried out on the structural and operational costs over a period of one year based on the statistical correlation of the population equivalent to the pollution load. These mathematical values were then related to the estimated price index and the sewage economy (that is, the daily operational and constructional cost of treatment plants in relation to the quantity of sewage to be treated). The costings were based on mathematical evaluations of oxidation ditches with and without aeration; automatically-controlled sewage works; percolating-filter plants with Emscher tanks and percolating-filter plants with sludge digestion; and activated-sludge plants. Although results obtained can be related to the exponential functions under standard conditions, normally a coefficient of variation of low percentage exists, which can be easily adjusted. A bibliography of 37 references is appended.

Keywords: cost, mathematical models, operational data construction cost, and correlations.

CAPITAL AND OPERATING COSTS—AWT

D. R. Evans and J. C. Wilson
Jour. Water Poll. Control Fed., 44, 1 (1972)

A valuable water resource for recreation, irrigation, and perhaps direct reuse has been produced at South Lake Tahoe, California. Advanced wastewater treatment techniques were used to supplement conventional activated sludge treatment. Advanced treatment, using lime, begins with phosphorus removal and secondary effluent clarification. Spent lime mud is recalcined in a multihearth furnace. Lime clarifier effluent flows through an ammonia-stripping tower to a two-stage recarbonation system; recarbonated effluent is put through mixed-media filters and carbon columns. Costs in 1969 for the conventional treatment were $172/mil gal ($56.00/1,000 cu m). These figures include capital and operating expenses.

Keywords: activated sludge process, adsorption, advanced wastewater treatment, California, carbon, costs, design, lime, maintenance, nitrogen, operation, phosphorus, reclamation, recreation, reuse, and South Lake Tahoe.

COST AND PERFORMANCE ESTIMATES FOR TERTIARY WASTEWATER TREATMENT PROCESSES

Robert A. Taft Water Research Center, Cinn., Ohio
R. Smith and W. F. McMichael

Available from the Clearinghouse as PB-1 $3.00 in paper copy, $0.65 in microfiche. A Taft Water Research Center Report No. TWRC-9, Federal Water Pollution Control Administration (June 1969)

Generalized estimates of both performance and cost are presented for wastewater treatment processes which can be used with activated sludge process to reduce the pollution load on the receiving stream. Processes and groups of processes believed to be leading candidates for use downstream of secondary treatment are listed. Data from various sources on the fraction of 5-day BOD associated with suspended solids are tabulated. Microscreening or rapid sand filtration removes about 42% of the 5-day BOD and 21% of the COD and TOC. Other solids-removing processes, such as lime clarification, multimedia filtration, and granular carbon adsorption, remove a greater fraction of the suspended solids. Some of the dissolved organic contaminants might be removed by granular carbon adsorption. Estimates of the concentrations of BOD, COD, TOC, nitrogen, and phosphorus downstream of each group of processes are tabulated. Estimates of capital and operating and maintenance costs for each process are shown.

Keywords: tertiary treatment, waste quality, cost analysis, performance, activated sludge, oxidation, filtration, sewage treatment, sludge, water pollution control, lime clarification, ammonia stripping, and microscreening.

A COMPILATION OF COST INFORMATION FOR CONVENTIONAL AND ADVANCED WASTEWATER TREATMENT PLANTS AND PROCESSES

Federal Water Pollution Control Administration, Cincinnati, Ohio. Water Research Lab
R. Smith

Available from NTIS as PB-206 430, $3.00 in paper copy, $0.95 in microfiche. Advanced Waste Treatment Laboratory, Research Division, (Dec. 1967)

The cost associated with building and operating wastewater treatment plants or individual wastewater processes has always been difficult to estimate for planning purposes. A great deal of information is available and an attempt has been made to assemble this information in one place using a consistent set of assumptions and omissions. It is hoped that this will prove a useful working document for engineers and scientists working in the field of wastewater treatment. Costs for conventional treatment plants include those for primary sedimentation, activated sludge and trickling filter plants. Advanced treatment processes considered in this collection are: solids removal by coagulation and sedimentation; filtration through sand or graded media; ammonia stripping, granular carbon adsorption; electrodialysis, microstraining of secondary effluent; chlorination of secondary effluent; and pipelines for ultimate disposal. Also, added are construction costs for individual equipment, structures and consumable items. Costs are normalized to June 1967 and are presented as national averages to allow adjustment of these figures to reflect current cost indices and local situations. This is not a complete consideration of the subject, but is a compilation of a very large amount of data in one document and in a form suitable for use by those in the wastewater treatment field.

Keywords: waste water treatment, costs, construction costs, operating costs, operation and maintenance, activated sludge, trickling filter, coagulation, filtration, activated carbon, electrodialysis, aeration, chlorination, pipelines, treatment facilities, comparative costs, primary sedimentation, ammonia stripping, and microstraining.

TREATMENT PLANT EQUIPMENT AND FACILITIES MAINTENANCE

Sewage Treatment Div., Los Angeles, Calif.
W. F. Garber

Journal, Water Pollution Control Federation, Vol. 42, No. 10, Pages 1740—1770 (October, 1970)

The increasingly stricter standards applied to pollutant discharges have resulted in wastewater treatment plants of increasing complexity. This increased process complexity, coupled with automatic process control has caused a sharp increase in service personnel for repair and maintenance of equipment, and a corresponding decrease in the operational personnel. Several factors have recently come tolight in the form of responses to questionnaires sent to many larger treatment plants. Most administrators realized that the wastewater treatment plants have no body of skilled workmen to call on, and must institute their own training institutions in order to provide the necessary manpower. In addition, many equipment suppliers are including information with their product, providing installation and preventative maintenance forms to aid in achieving proper operation from the equipment. Samples of repair shop organization, manpower organization, and preventive maintenance forms for various facilities are presented.

Keywords: wastewater treatment, installation, manpower, operation and maintenance, management, automation, equipment, instrumentation, training, economic feasibility, technical feasibility, lubricants, repairing, treatment facilities, skilled craftsmen, preventative maintenance, control forms and modifications.

SUPPORT MATERIAL

As in most literature searches, the investigators unearthed relevant material that defied logical inclusion in any one of the principle search areas. A collection of these "displaced" articles is presented under the unification of the support material category; it includes writings on some of the unconventional but newly emphasized areas related to wastewater treatment. Literature for this catchall category was collected from most of the leading instrumentation control and automation journals published from 1968 to 1973.

The principal criteria for inclusion in the support material literature search embodied the following:

- Articles that contained information relevant to the main objective of this literature search
- Writings that, in the investigators' opinion, implant principles and practices helpful to those concerned with automating wastewater systems.

Undoubtedly many good manuscripts have been omitted, but an extensive search of interesting peripheral articles is beyond the intended scope of this study.

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STORM OVERFLOW PERFORMANCE STUDIES USING CRUDE SEWAGE

P. Ackers, A.J. Brewer and A. E. Birbeck
Symp on Storm Sewage Overflows (May 4, 1967)

Experiments were carried out to: (a) determine the difference in composition of storm sewage discharge from an overflow and that passed to treatment; (b) compare the performance of the different types of overflow; (c) examine the effectiveness of scum boards; and (d) measure the changes in flow to treatment with increasing total flow in each structure. The types of overflow tested were: (a) a low double side-weir; (b) a stilling pond; (c) a vortex; and (d) a high-level side-weir with a positive flow control. The structures tested were designed to operate under hydraulic conditions as nearly identical as possible. The overflows were designed to spill at a discharge to treatment of 1/10 the maximum discharge and, with the exception of the low side-weir, would limit the flow to treatment to 20% above the first spill discharge. The most practical form seemed to be the round-crested type. Measurements were made of: (a) the discharge to treatment at first spill; (b) the discharge to treatment and spill at various larger incoming flows; and (c) the water levels in the overflow chamber for these discharges. The high side-weir had the best general performance, second was the stilling pond with the scum board 6 in. from the crest, and the vortex overflow was the worst.

Keywords: overflow, storm runoff, sewage treatment, weirs, stilling basins, flow control, design and discharge (water).

THE QUALITY OF STORM WEATHER FLOW

G. Akerlindh
Satryck ur Nordisk Hygienisk Tidskreff, Vol. 31, No. 1 (1950)

The quality of storm-water flow, particulary the surplus discharge from combined sewers, is discussed in order to compute the required regulated flow; that is, the amount of flow to be diverted for disposal. The three elements constituting storm-weather flow—namely sewage, ground water, and rain water, have been considered. Coliform bacteria in samples taken from streets (high runoff coefficients) and parks (low runoff coefficients) were compared. The concentration of organic matter in rain water is comparatively great (B. O. D. 100 to 200 ppm) being nearly as polluted as sewage. In regard to coliform organisms, however, the rain water portion of the storm-weather flow has a density of 100 to 1,000 per ml and, accordingly, is much lower than sewage and has a diluting effect on the sewage. The composition of rain water flow varies greatly and indefinitely. Despite this, it is reasonable to assume a constant composition.

Keywords: storm runoff, overflow, coliforms, sewage, water quality, biochemical oxygen demand, rain water and combined sewers.

COMBINED STORM SEWERS

A SIMULATION TECHNIQUE FOR ASSESSING STORM AND COMBINED SEWER SYSTEMS

J.A. Lager
Combined Sewer Overflow Seminar Papers, Edison, N.J. (Nov. 4—5, 1969); Water Pollution Control Research Series, Report DAST-37, pages 151—170 (Mar. 1970)

This paper describes work in progress to develop an assessment technique for comparing alternate solutions through a comprehensive computerized program capable of 'representing urban stormwater runoff phenomena, both quantity and quality, from the onset of precipitation on the basin, through collection, conveyance (both combined and separate systems), storage, and treatment systems to points downstream from outfalls which are significantly affected by storm discharges'. The program is intended for use by municipalities, government agencies, and consultants as a tool for evaluating the pollution potential of existing systems, present and future, and for comparing alternate courses of remedial action.

Keywords: simulation analysis, assessments, computer programs, storm runoff and water pollution control.

OVERFLOW STUDIES AT A SEWER SYSTEM OF A METROPOLITAN CITY

W. v.d. Emde and S. Hoffman
Gas Wasserfach (GAWFAN), Vol. 110, No. 12, pages 321—325 (Mar. 1969)

For determining the capacity of the sewer system including stormwater drainage in Hamburg, the flow speed, the water level, and the sludge deposition during dry weather were measured. The speed is found to be approximately 0.5 m/sec, and sludge deposition is hardly avoidable at the low inclination of the canal system. The conditions during rainy weather were determined with automatic level recording units. From these level measurements the frequency of overflow in days/year, the overflow duration in hours/year, and the overflow quantity/year were calculated.

Keywords: sewers, measurement, storm runoff, overflow, parametric hydrology, rainfall, mathematical studies, capacity and Germany.

CHARACTERIZATION AND CONTROL OF COMBINED SEWER OVERFLOWS, SAN FRANCISCO

D.W. Eckhoff, A.O. Friedland and H.F. Ludwig
Water Res, Vol. 3, No. 7, pages 531—543 (1969)

In order to find methods for controlling or treating storm-sewage overflows from combined systems in urban areas, overflows from the combined sewerage system of San Francisco were measured and sampled for analysis at two outfalls in the city. The dry-weather flows were also monitored. From the data obtained and other observations, the annual runoff for the whole of the city was compared with its total annual discharge of treated sewage effluent, and the effects of the dry-weather flow on the overflow and of the overflow on receiving waters were investigated. The latter effect produced a considerable increase in the numbers of coliform bacteria which remained higher than normal for about two weeks. The studies showed that treatment of overflows from combined systems could result in a substantial reduction of pollution at less expense than would be involved in separating the systems, and that dissolved-air flotation with chlorination appeared to be a promising method.

Keywords: overflow, outlets, analytical techniques, runoff, sewage treatment, San Francisco and storm sewage.

COMBINED SEWERS MAY BE AN ADVANTAGE

F.I. Vilen
Am City, Vol. 85, No. 1, pages 68—70 (Jan. 1970)

An alternative to separation, which utilizes combined sewers in conjunction with activated sludge treatment plants, is being put into operation in Kenosha, Wisconsin through a FWPCA grant. The plant employs the biological-adsorption process and can treat up to 20 mgd of combined sewage. Details of how the system works are included as well as a flow sheet diagram of the plant. The plant will save the city at least $6 million over sewer separation and during dry weather portions of the system can supplement normal plant operations. The plant will treat flow from only 70—80% of the storms, but because of the 'first flush' action of storm runoff, the greatest bulk of BOD and suspended solids will be captured. Parameters to be measured and evaluated to determine the efficiency of the system are listed.

Keywords: sewers, design, storm runoff, biological treatment, separation techniques, Kenosha, Wisconsin, combined sewers and sludge treatment plants.

INCREASING WASTEWATER FLOW VELOCITY BY USING CHEMICAL ADDITIVES

Western Co. of North America. Richardson, Tex. and Southern Methodist Univ., Dallas, Tex.
J.L. Overfield, H.R. Crawford, J.K. Baxter, L.J. Harrington and I.W. Santry, Jr.
Journal of the Water Pollution Control Federation, Vol. 41, No. 9, pages 1570—1585 (Sept. 1969)

Practical methods have been developed to increase waste water flow velocity by using chemical additives without increasing the energy needed to move the liquid. Existing sewer line flow can be increased by using polymer additives that would increase the solid removal effectiveness at treatment plants. A 100 ft long 6 in. sewer line test facility along with 25,000-gal controlled-temperature reservoir is used to determine the increased water flow with addition of chemical additives. There is a rapid increase up to 24 times the normal flow. Flow could be increased by a factor of 2 or more by using concentrations of additives between 45 and 200 ml/l. The cost/benefit analysis for a given example shows that the cost of rectifying overflow from a constriction by using an additive injection system, is less than half the prorated cost of constructing a parallel pipe system to relieve the condition. However, if the overflows occur ten times a year, the additive injection system becomes more expensive. Biochemical studies conducted indicate that additives do not affect adversely the waste water bacteria, fish, or promote algae growth. Further, the additives improve waste water settling and sludge drying rates. Additive injection system, through preferable economically in many cases, cannot be applied as a long term solution.

Keywords: additives, flow rate, waste water, algae, sludge, storms, turbulence, pilot plants, bacteria, sedimentation, toxicity, cost-benefit analysis, polymers, biological life, algae blooms, fish toxicity test, sludge drying, solids-settling, economic advantage, and temperature-effect.

QUANTITY AND QUALITY RELATIONSHIPS FOR COMBINED SEWER OBERFLOWS

San Francisco, Calif., and Engineering-Science, Inc., Oakland, Calif.
A.O. Friedland, T.G. Shea, and H.F. Ludwig

Fifth International Water Pollution Research Conference, San Francisco, Preprint, Paper I-1 (July 26—Aug. 1, 1970)

The results of a one year program of wet and dry weather monitoring of five combined sewer systems and one storm sewer system in San Francisco, is presented. The time concentration profiles of combined sewage constituents follow a definite three-phase variation initially having characteristics of raw sewage increasing in the second phase to 125 to 200% of the characteristics of raw sewage, and receding in the third phase to levels of 10 to 25% of the characteristics of raw sewage. No correlation was found between the mass emission of constituents due to storm and the antecedent dry period, land use character, or rainfall intensity. Storm runoff emission equations for COD total suspended solids total nitrogen, ortho-phosphate phosphrous. Hexane extractable material and floatables can be used in conjunction with dry weather flow, waste load coefficient, a rainfall history, basin acreage and population to estimate waste water loads. Weather diversions contain twice the total nitrogen and orthophosphate phosphrous, 50 to 60% more total nitrogen and COD, 20% more floatables, and 10% more total suspended solids than the storm runoff fraction of the diversion alone would contain. The nitrogen and phosphrous emissions from secondary forms are significantly greater than emissions of these constituents from combined or storm sewage flows on an annual basis.

Keywords: monitoring, flow, hydrology, mathematical models, hydrograph, storm runoff, storage, waste water treatment, water pollution, water quality and combined sewage.

INSTRUMENTATION AND CONTROL AT DALMARNOCK SEWAGE DISPOSAL WORKS

Water Waste Treatment, Vol. 12, No. 1, pages 19—20 (May/Jun 1968)

The instrumentation and control provided by the Lea Recorder Co. for the new activated sludge plant at Dalmarnock, Glasgow, are described in detail. Provision has been made for automatic sampling at various stages of treatment, as well as for the control and recording of the flows of sewage, stormwater, and effluent. The final effluent is discharged to the River Clyde.

Keywords: sewage treatment, flow measurement, sludge treatment, effluents, wastewater treatment.

PRIME NEED: INSTRUMENTS FOR USE IN FIELD

R. J. Bender
Power, Vol. 14, No. 10, pages 50—53 (Oct 1970)

As demand for pollution control has increased, so has the need for adequate instrumentation. Control of water pollution has reached a standard clearly ahead of air pollution control, and resolves itself into a matter of cost. Water management is becoming increasingly popular; monitoring instruments include pH meters. turbidity indicators, dissolved-solids recorders, DO, BOD, and COD meters, oxidation-reduction-potential sensors, and chemical analyzers. The article contains recent developments in the following areas of methodology instrumentation: the carbonaceous analyzer atomic absorption, sewage treatment monitors, telemetry, and flow meters.

Keywords: water pollution control, instrumentation, monitoring, administration, methodology, pollutant identification and measurement.

DEVELOPMENT AND PERFORMANCE OF A MOBILE WATER QUALITY MONITOR

R. W. Raibler and M. K. Testerman
Advan Instr, Vol. 24, Part 3, 5 pages (1969)
Presented at the Instrument Society of America, 24th Annual Conference (Oct 27—30, 1969)

A mobile water quality monitor intended for extended unattended use in locations where power lines are not available and for survey use is described. All solid state electronics are employed. Field tests have been performed for the past 2 1/2 years. Conclusions and problems concerning the monitors and transducers will be reviewed. Suggestions for future development are given.

Keywords: instrumentation, control systems, monitoring, pollutant identification, data collections.

SAMPLING AND MEASUREMENT IN THE AQUATIC ENVIRONMENT

Washington State Univ., Pullman. Dept. of Sanitary Engineering
S. K. Bhagat, D. E. Proctor and W. H. Funk
Water and Sewage Works, Vol. 118, No. 6, pages 180—187 (June 1971)

This report is largely based on our water quality studies of Vancouver Lake, which in its present condition is polluted and therefore, is of very little value to the nearby communities of Vancouver, Wash., and Portland, Ore. However, this inland body of water, with approximately four sq mi (2620 acres) of surface area, has the potential of becoming a useful multipurpose resource. The Vancouver Lake studies are related to the determination of present water quality conditions, evaluation of the sources of pollution and the exploration of ways to improve the usefulness of this resource.

Keywords: water pollution sources, water quality, water pollution effects, water pollution control, data collections, water chemistry, chemical analysis, lakes, streams, Washington, Oregon, ecology and Vancouver Lake (Wash).

INSTRUMENTS FOR WATER QUALITY MONITORING

Environmental Protection Agency, Cincinnati, Ohio
D. G. Ballinger
Environmental Science and Technology, Vol 6, No. 3, pages 130—133 (Feb 1972)

The waste parameters that must be monitored by industries discharging waste waters into navigable waters are reviewed together with recommended analytical procedures. The range and accuracy of some of these methods are listed and the cost ranges are given. Equipment and instruments available for these analyses are shown. It is pointed out that field equipment for on-line measurement of many of the required waste constituents is lacking. Manufacturers should begin constructing equipment specifically for waste conditions, rather than assuming that stream monitoring equipment will be adequate.

Keywords: instrumentation, water quality, monitoring, water quality control, analytical techniques, water analysis, industrial wastes, pulp wastes.

THE SYSTEM APPROACH TO SIGNAL CONDITIONING

Edgerton, Germeshausen and Grier, Inc., Albuquerque, N. Mex.
W. R. Edgel
IEEE Transactions on Instrumentation and Measurements, Vol. IM-20, No. 4, pages 201—205 (Nov 1971)

A complete highly flexible signal conditioning system for matching transducers to readout devices is described. This system differs from conventional systems in that all the components for a matching channel are packaged and powered together in one mainframe that provides the interconnections. The system gains tremendous advantages in flexibility, space, heat production, 'connectorology', and cost. Any matching channel can be synthesized by combining appropriate transfer functions. The system provides five types of components that provide power supply, input, preamplifier, processor, and dual output transfer functions. In each category, the number of transfer functions for which components can be designed is limited only by the user's imagination. By proper selection of components, the system can be used to match a wide variety of transducers and readout devices. The analysis and synthesis techniques are applied to several commonly used matching systems as a means of indicating the flexibility of the system.

Keywords: instrumentation, electron equipment, data transmission, equipment, data processing, automation, systems analysis, signal conditioning, recorders, transducers, systems design, channel matching and readout devices.

PROBLEMS OF TELEPHONE COMMUNICATIONS IN TELEMETRY

BIF, Providence, R.I.
J. R. Dancker
Journal of the American Water Works Association, Vol. 62, No. 11, pages 729—731 (Nov 1971)

The amount of telemetered data that will be added to municipal water production and distribution systems in the next 10 years probably will exceed all that was gathered before. One cause of this is the necessity to control and police water sources which requires water quality monitoring both for the input to treatments and the effluents from them. The growth in this area will require the solution to many problems of telephone communications in telemetry. The area of greatest concern is that of proper data channel planning and selection. This paper discusses that area in general terms and suggests approaches to meeting these problems. The importance of long-range planning is emphasized. This includes bringing together personnel of the municipality, the telephone company, and the manufacturers. The importance of economic evaluations of terminal hardware and the communications network are discussed and the necessity for defining engineering decisions in language that will be meaningful to the ultimate user of the system is emphasized.

Keywords: telemetry, water quality control, monitoring, effluent and communication.

TELEMETRY STATE-OF-THE-ART

Geological Survey, Washington, D. C.
G. F. Smoot
Proceedings of the National Symposium on Data and Instrumentation for Water Quality Management, Conference of State Sanitary Engineers and Wisconsin University (July 21—23, 1970), Madison, Wis. pages 234—242 (1970)

There are many choices available for designing a telemetering system, and the decision as to which is most satisfactory depends upon the specific need of the user. However, because needs and programs for water quality management are still evolving, any monitoring system should offer easy expansion as requirements change, and the flexibility to be converted to a more sophisticated system. With this approach, one can gain experience with a basic system, and expand as required.

Keywords: telemetry, data collections, water quality, monitoring, instrumentation, hydrogen ion concentration, electrical conductance, water temperature, oxidation-reduction potential, dissolved oxygen, turbidity, chlorides, fluorides and water quality sensors.

ON THE ANALYSIS AND USE OF WATER QUALITY DATA

Kansas State Univ., Manhattan. Dept. of Chemical Engineering
L. T. Fan, J. S. Shastry and L. E. Erickson
Proceedings of the National Symposium on Data and Instrumentation for Water Quality Management, Conference of State Sanitary Engineers and Wisconsin University (July 21—23, 1970) Madison, Wis., pages 313—324 (1970)

One of the primary reasons for water quality data collection is that of enforcement of water quality standards. Water quality data are also very useful to those investigating the ecology of streams and estuaries. Systems analysis techniques such as parameter estimation and spectral analysis may be used in the analysis of data and construction of models that enable the investigator to better understand the assimilative capacity of the stream and the effect of discharges on stream ecology. Water quality data may be collected continuously, periodically at infrequent specified time intervals, or ocassionally at infrequent time intervals. Spectral analysis requires a large volume of data at a very small sampling interval. The shortest period that is necessary to resolve determines the sampling interval, and the longest period necessary determines the total record length.

Keywords: data collections, water quality, statistical methods, systems analysis, time series analysis, correlation analysis, frequency analysis and water quality data.

SENSORS STATE-OF-THE-ART

Geological Survey Washington, D.C.
J. H. Ficken
Proceedings of the National Symposium on Data and Instrumentation for Water Quality Management, Conference of State Sanitary Engineers and Wisconsin University (July 2—23, 1970), Madison, Wis, pages 224—233 (1970)

The water quality parameters most commonly measured and recorded by the U. S. Geological Survey are electrical conductivity, temperature, pH, and dissolved oxygen. Parameters less frequently monitored include turbidity, oxidation-reduction potential, chloride, and fluoride. This paper describes briefly some types of sensors now in use by the U.S. Geological Survey for monitoring the water quality in lakes, streams, and reservoirs.

Keywords: telemetry, data collections, water quality, monitoring, instrumentation, hydrogen ion concentration, electrical conductance, water temperature, oxidation-reduction potential, dissolved oxygen, turbidity, chlorides, fluorides, and water quality sensors.

INSTRUMENTATION FOR WATER POLLUTION CONTROL

R. H. Jones
Pollution Engineering, 3(6) pages 22—23 (Nov/Dec 1971)

A modern treatment plant handling tens of millions of gallons of wastewater per day operates on instrumental control. Instrumentation used in water pollution control has a two-fold purpose to detect and measure the pollutants and to automate and control the processes for their removal. Most measurements made instrumentally in a waste treatment plant are physical in nature; e.g., flow, level, pressure, and temperature. However, demand for greater treatment efficiency is leading to increased use of analytical or composition measuring instruments.

Keywords: instruments, water pollutants, water quality control, wastewater, treatment plants, physical, analytical, process control, automation efficiency.

DESIGN OF AN AUTOMATIC MONITORING SYSTEM

Geological Survey, Austin, Tex. Water Resources Div.
J. F. Blakey
Proceedings of the National Sumposium on Data and Instrumentation for Water Quality Management, Conference of State Sanitary Engineers and Wisconsin University (July 21-23, 1970), Madison, Wis., pages 243—246 (1970)

To provide the required data as soon as possible, the U. S. Geological Survey continuously tests, evaluates, and applies modern analytical tools and approaches. One of the most important analytical tools adopted by the Survey in recent years is the automatic water quality monitor. This paper describes the development, design, and operation of such units. The Survey presently has some 300 water quality monitors in operation, including 125 multiparameter potentiometric systems, 150 resistance-type units, and about 30 analog strip chart monitors. The single most important factor in monitor operations is trained field personnel. The Survey's training program includes individual instruction in all phases of monitor installation and operation. The reliability of monitoring equipment is gradually improving. The Survey installs, operates, and improves monitors as the need for data increases and as the state-of-the-art allows.

Keywords: telemetry, data collections, water quality, monitoring, instrumentation, hydrogen ion concentration, electrical conductance, water temperature, oxidation-reduction potential, dissolved oxygen, turbidity, chlorides, fluorides and water quality sensors.

INSTRUMENTATION IN WATER POLLUTION CONTROL ANALYSIS

T. Williamson and A. S. Millar
Water Pollut. Control, London, pages 70, 90—94 (1971)

The authors describe briefly the use of instrumental methods by the Lothians River Purification Board for monitoring river waters; the instruments used include an AutoAnalyzer (see Wat. Pollut. Abstr., 1970, 43, Abstr. No. 65), an atomic-absorption spectrophotometer, and a gas-liquid chromatograph. The advantages of using instruments over manual methods are indicated.

Keywords: instruments, automatic atomic-absorption, gas-liquid chromatograph and water quality.

MONITORING WATER QUALITY WITH A SUBMERSIBLE DEVICE

G. F. Hodges
Contr. & Instrum., 3, No. 5, pages 27—29 (1971)

The development, design, and construction of a self-contained, battery-powered, submersible, water-quality monitoring instrument is described. A sensor assembly in the head of the unit automatically measures conductivity, dissolved-oxygen concentration (by Mackereth electrode), pH value, suspended solids (by an optical density probe), and temperature of the water. The base of the instrument has a time switch for starting the measuring cycle, and a recorder unit where measurements are stored on magnetic tape, which can be processed to punched paper tape for computer infeed.

Keywords: water quality, instruments, sensors, continuous and computer.

AUTOMATIC MEASURING DEVICES AND EQUIPMENT FOR THE CONTROL OF WATER QUALITY IN STREAMS AND THE TREATMENT OF SEWAGE

H. Graefen and F. Malz

Gas-u. WassFach, 111 pages 199—205 (1970) (in German)

An illustrated account is given of recent developments in the design and application of automatic measuring instruments for the control of continuous sewage-treatment processes, with particular reference to the industrial area of North Rhine-Westphalia which is under the water management of the Lippeverband and the Emschergenossenshaft. Reports are given of the automatic control station which has been constructed for the new sewage works at the confluence of the river Seseke with the Lippe, where special instruments are built into a large control panel to analyze and control the incoming sewage load and suspended solids and carry out continuous measurements on conductivity, temperature, oxygen demand and pH value. Continuous toxicity tests are carried out in streams to assess the decrease or increase of the fish population and determine the water quality.

Keywords: water quality, automatic, instruments, control, toxicity and continuous.

WATER TREATMENT PLANT AUTOMATION IN THE UNITED KINGDOM

Binnie and Partners, London (England)
J. H. T. Griffiths
Journal of the American Water Works Association, Vol. 62, No. 8, pages 473—482 (August 1970)

With the cost of a man capitalized at approximately $42,000 it has become necessary to look to automation for an answer to increased production costs. An account of the development of automation in the water treatment industry may be of some help to the operator. In 1949, Permutit installed a battery of four gravity filters with automatic wash capability. In 1952, the first plant with automatic filter wash and centralized control was commissioned at Broadside Works. The Sandford Mill softening plant introduced the use of grain handling techniques for the pneumatic handling of lime and soda ash. This led to automation of the storage, handling and preparation of chemicals. Automated sludge handling followed in 1956. The Elvington works, commissioned in 1960, was the first fully automated water works in the U.K. The plant is manned 48 hours each week. The balance of the time, the plant operates under automatic control without operators. Provisions are made for alarm devices to signal standby personnel in the event of emergencies. Data logging is an essential part of automation to record the effectiveness of operations when no personnel are present. Full automation of the mechanical processes in a water treatment plant is reliable, efficient and can save staff. It will be increasingly adopted in the future.

Keywords: waste water treatment, water treatment, automatic control, hydraulic valves, water quality, treatment facilities, automation, mechanical control, control system, operations, operating costs, pneumatic handling devicbs and United Kingdom.

INSTRUMENTATION

MEASURING PROCESS VARIABLES

D. E. Zientara
Chem. Eng. Vol. 79, No. 20, 19 pages (1972)

A key guide to selecting and operating instruments for measuring 5 key process variables—temperature, pressure, flow rate, level density and viscosity—is presented. Three tables summarize methods of measurement, primary elements, operating ranges, accuracy, costs and advantages and disadvantages of the particular method of temperature, flow and density determinations. Accuracy includes conformity, hysteresis and repeatability characteristics; and it is usually expressed in percent of full scale.

Keywords: measurements, physical, accuracy, costs and process control.

ON-LINE PROCESS ANALYZERS

T.J. Kehoe
Chem. Eng. Vol. 79, No. 20, 33 pages (1972)

Recent innovations in automatic composition analyzers emphasize coordinated system and special purpose instruments rather than new analytical techniques. The major thrust of new instrument development has focused in the environmental control field; but the chemical processing industry will eventually profit from this emphasis. A multi-instrument water quality monitoring system in Ohio is briefly described; better low level calibration methods are needed.

Keywords: chemical sensors, water quality, instruments and analytical techniques.

WATER QUALITY MONITORING MUST BE ACTION ORIENTED

V. T. Stack
Wat. Wastes Engng, 8, No. 3, pages B10—B12 and B14—B16 (1971)

The author discusses factors to be considered in setting up a system for automatic monitoring of water or waste waters and describes some examples of commercially available monitoring systems. He stresses the fact that the system should include facilities for initiating corrective action when indicated by the data received.

Keywords: automatic, continuous, process control, corrective action and analytical sensors.

BIOLOGICAL MONITORING OF THE EFFLUENT FROM A LARGE CHEMICAL WORKS IN A RIVER WHICH HAS SOURCES OF POLLUTION UPSTREAM

Canadian Industries Ltd., Montreal (Quebec)
N. E. Cooke, R. M. Cooper and T. W. Beak
Fifth International Water Pollution Research Conference, San Francisco (July 26—August 1, 1970)

In order to protect themselves and reassure the control authority, some forward looking chemical companies are undertaking biological monitoring before and after plant start-up. The effluent was to be discharged into the St. Clair River, where there was already considerable pollution. To complicate the development of the system to monitor the effluent from the new plant the existing pollution in the river was of a random nature indicating that there were intermittent discharges, or spills of pollutants from the industries situated upstream. Mathematically, the problem was to find a statistical method which would enable the company to separate the effects of its plant effluents from the random effects of the other effluents coming down from upstream. The invertebrate fauna found on the bottom consisted almost entirely of chironomicae pelecypoca, gaftropoca, and oligiochafta. Due to the presence of pollution the more sensitive organisms had already been eliminated. A series of charts were developed which would indicate the differences between the averages from upstream and downstream locations in each biological survey. This permits one to detect a significant change caused by material discharged through the outfall in spite of very large fluctuations in the number of animals caused by random discharges of polluting materials released upstream.

Keywords: monitoring, water pollution control, rivers, mathematical models, probability, statistics, waste water treatment, testing, sampling, biological monitoring, and chemical pollution.

A RATIONAL EVALUATION OF INSTRUMENTATION AND CONTROL SYSTEMS

C. A. Maguire and Associates, Inc., Waltham, Mass.
R. H. Babcock
Preprint, presented at 44th Annual Conference of the Water Pollution Control Federation, Session 2, No. 1, 17 Pages (1971)

The dramatic increase in the use of instrumentation in waste treatment plants over the last two decades has produced its share of attendant problems, not the least of which is the inadequate support for, and frequent misuse of, the useful devices in that field of application. Perhaps the primary contribution to this problem has been the dearth of qualified men for the maintenance of automated systems, and the lack of any coordinated training program in this field to correct the situation. As the trend for the future is for larger and more sophisticated fully automated plants, it is suggested that a practical solution is the use of specialized companies for maintenance on a contract basis. The complex and varied nature of waste processing required that serious thought be given to the degree and type of instrumentation. The question of pneumatic versus electronic devices is debatable. Unless the problem of maintenance is properly addressed and resolved, the use of electronics will be seriously hindered. The advent of intrinsic safety standards can simplify and economize on installations in hazardous areas. Since the general level of knowledge concerning instrumentation and automation is low, it is suggested that the water pollution control federation support workshops on this subject.

Keywords: waste water treatment, automation, instrumentation, maintenance, training, personnel, cost-benefit analysis, treatment facilities, intrinsic safety standards, workshops, hazardous areas and contract maintenance.

INSTRUMENTATION

ANALYSIS OF MUNICIPAL AND CHEMICAL WASTE WATERS BY AN INSTRUMENTAL METHOD

Dow Chemical Co., Midland, Mich. Analytical Science Lab.
V. A. Stenger and C. E. Van Hall
Journal of the Water Pollution Control Federation, Vol. 40, No. 10, pages 1755–1763 (Oct 1968)

An instrumental method based on a vapor phase oxidation mass reduction system utilizing carbon monoxide as a reaction product is discussed. Principle of operation and operating conditions is covered. The testing of samples includes primary and secondary municipal waste water, cellulose production wastes, and chemical wastes. Comparison between the instrumental (CO2D) and conventional (COD and TOC) tests are made. Results show comparable COD and CO2D values. A number of common compounds has shown results within 5% of the theoretical COD values. The results on some others particularly volatile compounds such as phenol or acetone, may be low by 10–15%. The presence of chloride (500 mg/l NACL) raises results by about 10 mg/l at the 100–200 mg/l COD level.

Keywords: analyzer, concentration, interference, oxidation reduction system, waste water treatment and instrumentaton.

INSTRUMENTATION FOR RESEARCH ON BIOLOGICAL PROCESSES

Moore Products Co., Knoxville, Tenn.
C. W. Crawford, K. Kambhu, and J. F. Andrews
Proceedings Industrial Waste Conference, 23rd, pages 1039–1053 (May 1968)

Many of the limitations of previous studies on biological processes used for waste treatment have been due to the many variables involved, time requirements for bringing the mirobial cultures to steady state, and a lack of control of some of the more important variables. Significant advances could be made in the solution of these problems by using appropriate instrumentation for automatic control and analysis of important variables and automatic collection and formatting of data for direct entry into a digital computer by using a data acquisition system. Measurement and control of process variables includes: (1) gas composition, (2) gas flow rate, (3) dissolved oxygen, (4) temperature, and (5) pH. A Beckman Dextire Data System was used for the automatic collection and formatting of data for direct entry into a digital computer. This is an expandable data acquisition complex which is designed to accept signals from various sensors located within several research laboratories and channel them to a centralized processing units. The instrumentation and data acquisition systems described have only recently been placed in operation and the results of operating experience are therefore not available.

Keywords: automatic control, biological treatment, data processing, instrumentation, research equipment, control, data collections, data storage and retrieval, digital computers, measurement, waste water treatment, data acquisition system and process variables.

RESEARCH AND DEVELOPMENT NEEDS FOR METROPOLITAN WATER INTELLIGENCE SYSTEMS

R. G. Poertner

National Technical Information Service PB-212-570 (1972)

A survey was made of existing and planned applications of instrumentation in water and wastewater systems of selected urban and metropolitan areas of the United States. The basic goal was to make available information concerning instrumentation and automation that would be useful to decision-makers in providing and operating such systems. The problems of planning, designing, implementing, maintaining, operating, and financing instrumented water and wastewater systems are reported. Two major technical problems were identified—the unreliability of telephone lines as a communications link between the field and the operations control center, and the excessive costs and manpower required to service and calibrate sensors used to measure water parameters. The major nontechnical problems highlighted the need to focus attention on determining how metropolitan areas will use and handle water in future years, and on educating and motivating public officials to investigate, encourage, and support sophisticated metropolitan water intelligence system. R&D needs are identified.

Keywords: research and development (R&D), water requirements, water resources development, urbanization, cities, automatic control, supervisory control, digital computers, water supply, wastewater treatment, water quality control, instrumentation, automation, electronic equipment, monitoring needs, technical problems and nontechnical problems.

NEW DIRECTIONS FOR WASTEWATER COLLECTION AND DISPOSAL

North Carolina University, Chapel Hill
D. A. Okum
Journal Water Pollution Control Federation, Vol. 43, No. 11, pages 2171–2180 (Nov. 1971)

An increasing number of problems is developing in finding new applications for renovated wastewater. Most authorities in the United States agree that, at the present stage of development, municipal wastewater treatment plant effluent can not be monitored and controlled closely enough to be considered a safe source of potable water. A considerable upgrading of virus and chemical detection and removal devices is necessary before such use is considered. However, reclaimed water has many applications in industrial, agricultural, and recreational uses. Many projects are presently in operation that recycle treated municipal wastes for industrial uses. Studies are also underway to determine the feasibility of using certain non-potable waters in the home in a separate system. To ensure continuance of these and other programs will require increasing numbers of young and talented engineers, and steps are currently being taken to ensure that all necessary manpower will be available.

Keywords: municipal wastes, tertiary treatment, water reuse, industrial water, land reclamation, irrigation, analytical techniques, cost analysis, water quality control, engineering education, personnel, research and development, and wastewater treatment.

THE CONCEPT OF WASTEWATER RECLAMATION

Cornell, Howland, Hayes, and Merryfield/Hill, Corvallis, Oregon
L. G. Suhr
Water Resources Research Institute Seminar, Wr 014.71, pages 33–49 (July 1971)

Wastewater may one day cease to exist as a word simply because no water will be wasted. Since the only water fit to throw away will also be fit to drink, due to increasingly stringent regulations, it will be used for drinking. Future plans for desalinization of wastewater before discharge into Lake Mead, California, would result in the effluent being polluted by contact with Lake Mead waters. Reclamation has already become a reality in Africa with the Windhoek Plant. Effluent from a plant using: 1) flocculation-flotation, 2) detergent removal by foam fractionation, 3) lime treatment, 4) chlorination, 5) settlement of calcium carbonate sludge, 6) sand filtration, 7) activated carbon adsorption, and 8) final rechlorination is stored in a maturation reservoir from which drinking water is drawn. Although this and other installations are evidence that the technological knowhow to reclaim effluents is available, the lack of adequate safeguards, monitoring devices, and public enthusiasm prevents widespread application. Reliability of these plants must be increased, new and faster monitoring devices must be developed, and people must be educated in water usage.

Keywords: water reuse, tertiary treatment, water consumption, research and development, separation techniques, ion exchange, foam fractionation, distillation, flocculation, flotation, sedimentation, lime, phosphorus, irrigation practices, wastewater treatment, and California.

WHERE DOES RESEARCH STAND IN WATER POLLUTION?

H. G. Hanson and B. E. Bergen
Journal Water Pollution Control Federation, Vol. 33, pages 477–484 (1961)

In this review three questions are answered: 1) who is doing research, 2) what is being done is research, and 3) what are the resources for doing research. Approximately two-thirds of all research is done by universities, and the remainder is done by industries, states, and municipalities. The research projects fall into six categories: 1) the origin and behavior of wastes, 2) the treatment of waste, 3) disposal of wastes, 4) stream monitoring and surveys, 5) the treatment of water, and 6) conservation. The nation's developed resource for research in water supply and pollution control is extremely limited. The report includes discussions on: 1) accounting for all the wastes that reach streams, 2) predicting the pollutional character of new wastes, 3) the adequate treatment of wastes, 4) the effective use of receiving water, 5) intelligent and effective monitoring of receiving waters, 6) the effective treatment of polluted water for reuse, and 7) the problems of separation and purification.

Keywords: separation techniques, water pollution, water pollution control, research, and purification.

A REVIEW OF THE LITERATURE OF 1964 ON WASTE WATER AND WATER POLLUTION CONTROL

Journal Water Pollution Control Federation, Vol. 37, pages 587–646, 735–799, 887–979 (1965)

The article discusses analytical methods; the determination of organic carbon, pesticides, phenolic compounds, organic compounds, metals, inorganic anions, nitrogen compounds, and dissolved oxygen; laboratory control of sewage treatment; biological filtration; the activated-sludge process; disinfection of sewage and water; the effects of synthetic detergents; sludge digestion; the disposal and utilization of sludge; lagoons; reuse of sewage effluents; starch and sugar factories, chemical industries, and textile and wool industries; methods for treatment of radioactive wastewaters and recovery of radionuclides; the removal of radioactivity from water and sewage; the underground and marine disposal of radioactive wastes; the uptake of radioactivity by bottom deposits and aquatic organisms; the measurement of radioactivity and methods for continuous monitoring; biology of polluted waters; water quality requirements for fish; the biological effects of pollution be sewage, detergents, industrial wastewaters, pesticides, and weedkiller; algae, fungi, and bacteria in polluted waters; methods for biological estimation of pollution; the effects of radioactive pollution; the microbiology and chemistry of polluted waters; oxygen sag and self-purification; the use of stream standards; surveys of polluted waters; legislation and control of pollution; the effects of pollution on water supplies; pollution of ground water and the polluting effects of ground water recharge; pollution of estuaries and seawater; and the disposal of wastewaters at sea.

Keywords: wastewater treatment, sewage treatment, analytical techniques, standards, legislation, pollutants, organic compounds, pesticides, phenols, inorganic compounds, nitrogen compounds, dissolved oxygen, biological treatment, filtration, activated sludge, disinfection,

detergents, sludge digestion, lagoons, canneries, dairy industry, fermentation, coal mine wastes, oil wastes, pulp wastes, radioactive waste disposal, radioactivity techniques, bacteria, biology, radioactivity effects, water supply, groundwater, microbiology, biochemistry, groundwater recharge, seawater, estuaries, wastewater disposal, self-purification, oxygen sag, surface waters, and textile wastes.

A REVIEW OF THE LITERATURE OF 1966 ON WASTE WATER AND WATER POLLUTION CONTROL

C. M. Weiss

Journal Water Pollution Control Federation, Vol. 39, No. 7, pages 1049—1154 (July 1967)

A review of papers published during 1966 is presented. The material covered includes: the biological studies evaluating water pollution, the causes of fish mortality, the toxic nature of substances in fresh water, water quality, detergents as related to algal growth and fish damage, domestic and industrial waste treatment, a metal toxicity assay, the effect of wastes from the pulping and forest industries, potential hazards from pesticide and herbicide residues, the effect of thermal discharges, physiological and pathological conditions in fish caused by toxic compounds, methodology and instrumentation, and estuarine and marine pollution.

Keywords: wastewater treatment, biological treatment, water pollution control, fish, toxicity, fresh water, pulp wastes, pesticide residues, metal toxicity, herbicides, estuaries, water quality, detergents, algal control, industrial wastes, thermal pollution, methodology, instrumentation, and seawater.

A REVIEW OF THE LITERATURE OF 1968 ON WASTEWATER AND WATER POLLUTION CONTROL—INDUSTRIAL WASTE, RADIOACTIVE

C. P. Straub

Journal Water Pollution Control Federation, Vol. 41, pages 1223—1251 (June 1969)

The following topics relating to radioactive industrial waste disposal were reviewed (with 167 references): U recovery, wastewater treatment by precipitation of radionucludes, solvent extraction, ion exchange, adsorption, uptake on natural materials, electrodialysis, and fixation; ground disposal; disposal in the hydrosphere (oceans, rivers); uptake on sediments; monitoring; and analysis. In the United States, increased emphasis is placed on concentrating, solidifying, and containing wastes. Only a nonhazardous, economically irreducible minimum of radioactive material is to be discharged into the environment. Waste management practice at nuclear power plants operates within the limits authorized for release of radioactive wastes to the environment at costs estimated to range between 2 and 10% of their total operating costs. The average activity in liquid wastes varies from 0.01 to 11.1 CI, exclusive of 3H. Tritum levels range from 5 to 1300 CI annually. The use of high-pressure washing and rewashing for leaching U from mined-out areas is referred to, and the removal of specific radionuclides by various treatments of wastewater is outlined. The presence of detergents affects the treatment of wastes by precipitation; the effect increases at increased detergent concentrations and generally increases with decreased pH. How 90 SR is extracted from various radioactive waste solutions at the Hanford B plant is explained. A study to determine if low-cost nuclear energy, heat, radiation, or electricity could be used to reduce the cost of wastewater treatment is reviewed.

Keywords: industrial wastes, water, control, water quality control, water pollution, water pollution control, water treatment, chemical precipitation, ion exchange, solvent extractions, adsorption, absorption, electrodialysis, waste disposal, oceans, rivers, sedimentation, monitoring, analytical technique, radioactive wastes, decontamination, and waste management.

PROCESS CONTROL

W. Skaggs
Chem. Eng. Vol. 79, No. 20, page 7 (1972)

On large process units, electronic instrumentation and control continues to edge out pneumatic devices because of lower installation costs, faster response and the increasing use of integrating circuits. No widespread use of one-line computers is seen in the next several years; package type mini-computers, complete with sensors and software will be more popular than large computer control systems. New on-line analytical sensors offer improved reliability at lower costs. To use complicated analyzers in process control, they must be essentially trouble free; easily operable and serviced promptly by factory personnel. Other advances include improved digital transmitters, quieter valves, and smaller central rooms.

Keywords: automation, process control, instrumentation, electronic, pneumatic, minicomputer, sensors and software.

WATER TREATMENT PLANT AUTOMATION IN THE UNITED KINGDOM

Binnie and Partners, London (England)
J. H. T. Griffiths
Journal of the American Water Works Association, Vol. 62, No. 8, pages 473—482 (August 1970)

With the cost of a man capitalized at approximately $42,000 it has become necessary to look to automation for an answer to increased production costs. An account of the development of automation in the water treatment industry may be of some help to the operator. In 1949, Permutit installed a battery of four gravity filters with automatic wash capability. In 1952, the first plant with automatic filter wash and centralized control was commissioned at Broadside Works. The Sandford Mill softening plant introduced the use of grain handling techniques for the pneumatic handling of lime and soda ash. This led to automation of the storage, handling and preparation of chemicals. Automated sludge handling followed in 1956. The Elvington Works, commissioned in 1960, was the first fully automated water works in the U.K. The plant is manned 48 hours each week. The balance of the time, the plant operates under automatic control without operators. Provisions are made for alarm devices to signal standby personnel in the event of emergencies. Data logging is an essential part of automation to record the effectiveness of operations when no personnel are present. Full automation of the mechanical processes in a water treatment plant is reliable, efficient and can save staff. It will be increasingly adopted in the future.

Keywords: waste water treatment, water treatment, automatic control, hydraulic valves, water quality, treatment facilities, automation, mechanical control, control system, operations, operating costs, pneumatic handling devices and United Kingdom.

WATER QUALITY AND TREATMENT: PAST, PRESENT AND FUTURE

Florida University, Gainesville, Department of Environmental Engineering
J. E. Singley and A. P. Black
Journal of American Water Works Association, Vol. 64, No. 1, pages 6—10 (Jan 1972)

Water treatment history is reviewed and potential processes and control parameter refinements requiring further investigation and application are cited. Water treatment design traditionally has been conservative. Some utilities have adopted polymers for use as primary coagulants and coagulant aids, and automatic monitoring and process control. Some have instituted individual research programs. The time lag between process development and plant adaptation must be decreased. Research considerations include process optimization, development of new control methods and coagulants, place and extent of mixing, increased automation, development of new filtration media, the effect of trace minerals and organics, improving disinfection, and sludge disposal. The utility of recovering and recycling MCC03 at purification facilities is discussed. A 50 gpm pilot plant at Montgomery, Alabama is evaluating this recycled coagulant for effectiveness in reducing color and turbidity.

Keywords: water treatment, automation, sludge disposal, magnesium carbonate, process control, and polymers.

APPLICATION OF CARBON TECHNIQUES TO BIOLOGICAL SYSTEMS

Southwest Research Inst., San Antonio, Tex.
L. L. Hiser and D. S. Tarazi
Chemical Engineering Progress, Symposium Series, Vol. 67, No. 107, pages 267—278 (1971)

Part of an in-house research project in carbon materials balance was conducted on a closed biological system. The conversion of dissolved organic carbon to carbon dioxide and suspended organic carbon (cell growth) was followed by monitoring all three phases, gas, liquid, and solid, of the closed system. A modified carbon analyzer was used for carbon determinations. An energy balance was made on the closed system by equating the oxygen equivalent of the carbon dioxide produced with the satisfaction of COD in the aqueous system. This approach was held valid for the carbohydrate substrate involved. An attempt was also made to obtain a volumetric oxygen balance. However, this attempt was unsuccessful owing to the loss of gas during the experiment and to the apparent production in the system of gases other than carbon dioxide. An approach is discussed for application of carbon and oxygen demand parameters to the control and monitoring of practical systems.

Keywords: carbon, biological treatment, oxidation, activated sludge, hydrogen ion concentration, chemical oxygen demand, biochemical oxygen demand, kinetics, surface waters, absorption, hydrogen effluents, waste water treatment, carbon analyzer, aerobic mass, total oxygen demand, dissolved organic carbon and suspended organic carbon.

REPORT ON OPERATIONS CONTROL CENTER FOR THE WATER UTILITY DEPARTMENT OF THE CITY OF DALLAS, TEXAS

Black and Veatch Consulting Engineers, Kansas City, Mo. (Feb 20, 1969)

Improvements were studied in the operation of the water supply and distribution system and the waste water system of Dallas. Suggestions are presented for expanding the existing telemetering system and the few existing supervisory control systems to establish a central operations control center. Supervisory control and data handling equipment is recommended for adaption at the earliest possible date to a control system employing a digital computer. The estimated cost of supervisory control and electrical equipment, together with valves and piping is approximately two million dollars. Additional costs would be involved if sewage treatment plants, lift stations and pumping stations are tied into the operations control center. More efficient operation of the water distribution system and the development of improved and expanded data handling and processing appear to be the principal reasons for the recommendations. Operating costs can be reduced by converting attended pumping stations to an unattended status.

Keywords: automation, automatic control, remote control, electronic equipment, supervisory control, data transmission, telemetry, control systems, mechanical control, model studies, distribution systems, monitoring, digital computers, treatment facilities, pumping plants, instrumentation, Texas, Dallas and operations control center.

OPTIMIZING WASTE TREATMENT CONTROL SYSTEMS

E. T. Williams, Jr.
Paper presented at the Third Annual National Pollution Control Conference and Exposition (April 1—3, 1970), San Francisco, California

As waste treatment and recovery processes become more complex and costly, there is increasing reliance upon instrumentation to assume control responsibility for the most economic and efficient operation. This paper describes the control systems normally used on four applications, and discusses what can be done to optimize performance. The use of dissolved oxygen and sludge density measurement in the activated sludge process is explored. The second application is pH neutralization. Feedforward control and the nonlinear controller have dramatically improved neutralization performance. Improvements are also suggested in the control schemes of chromate waste and cyanide waste treatment processes.

Keywords: instrumentation, waste treatment, control systems and measurement.

CHEMICAL FEED SYSTEMS DETERMINE PLANT EFFICIENCY AND RELIABILITY

Wallace and Tiernan, Inc., Beleville, N. J.
R. J. Baker
Water and Sewage Works, Vol. 116, No. 6, pages 214—217 (June 1969)

The application, design, and control of chemical feed systems for water treatment plants is considered. The typical chemical feed system is defined as consisting of chemical storage, preparation for feeding, feeding, preparation of application, application to the process, and related process and system controls. Each of these basic elements is discussed in regards to its importance and position within the chemical feed system seven factors are suggested for consideration: chemical selection, capacity, type of control, flexibility, future requirements, standby equipment and the need for instrumentation. Advance planning for alternatives can provide flexibility for the most suitable chemical for the process and the most economical plant operating costs. Further, variation or changes in process operation can be best accommodated if chemical alternatives are considered during design. Capacity is discussed from two view points: storage and equipment metering ranges, both of which can have considerable bearing on the flexibility and workability of the system as a whole. Manual, flow proportional, and feedback from process controls are discussed. Combinations of these on the compound-loop control system is suggested to be the more flexible under most conditions. Overall system flexibility is obtained by selecting equipment with a maximum of alternate uses. This type design will be readily adaptable to future requirements as well as satisfy some requirements for standby equipment.

Keywords: waste water treatment, design, equipment, chemicals, flexibility control systems, instrumentation, storage capacity, chemical feed systems and capacity.

AUTOMATIC WATER AND WASTE TREATMENT PLANTS IN OPERATION

Stone (Ralph) and Co., Inc., Los Angeles, California
E. T. Conrad

Civil Engineering, American Society of Civil Engineers, Vol. 40, No. 5, pages 37—40 (May 1970)

Water and waste treatment for the Napa—Berryessa Improvement District and Lake Perryessa in California depend on an automatic system. The water facilities are an intake structure; treatment plant which provides for taste, odor, and pH control clarification, filtration and chlorination; pump station; 7,000 ft transmission main; storage tank; and distribution system. The entire water system is controlled automatically using water levels at various points to start and stop the intake and booster pump stations. The intake pumps are mounted on a carrier and move up and down with the lake level. The system was designed for peak flows of 0.5 mgd, expandable to 1.0 mgd and ultimately to 4.0 mgd. The sewage facility treats a load of 0.175 mgd with easy expansion to 0.35 mgd incorporating and activated sludge plant followed by oxidation basins. Two booster pumps, controlled automatically by the level in the oxidation basin, pump the effluent to the disposal area. The treated waste is disposed through hillside irrigation employing 80 acres with natural slopes up to 1:1. The land was divided into four subdivisions: three sections intermittently irrigated by an automatically controlled 50,000 gal storage tank, and the fourth section allowed to fully dry between dosings. Drainage ditches and a collection pond prevent contamination of lake waters. The total construction cost was $735,644 with $32,324 going for the automatic control system.

Keywords: sewage treatment, water treatment, activated sludge, filtration, chlorination, oxidation, aeration, cost, waste water treatment, California, Napa-Berryessa Improvement District, automatic control and clarification.

THE USE OF COMPUTERS IN PHILADELPHIA'S WATER POLLUTION CONTROL ACTIVITIES

C. F. Guarino

Water Research, Vol. 6 (1972)

In 1966, the city of Philadelphia started using computers to reduce recordkeeping manpower for its treatment plants and to pave the way for eventual instrumentation and automation of wastewater treatment facilities. Through suitable programming, the computer generated a monthly report that tabulated plant data and performed all necessary calculations and statistical analyses. As an outgrowth of this program, maintenance-based data logging routines report conditions on the major equipment in Philadelphia's Northeast treatment facility. The author expects this information to be extremely useful in the design of new treatment facilities. Another use of the computer is to help develop and evaluate vital wastewater process control sensors, the largest obstacle in the path of automation.

Keywords: automatic data reduction, periodic maintenance logs, computer, process control, and instrumentation.

APPLICATION OF AUTOMATIC SAMPLING TO TODAY'S WATER QUALITY CONTROL PROGRAMS

Gurnhamand Associates, Inc. Chicago, Ill.
F. C. Gurnham and M. I. Beach
Proceedings, Ontario Industrial Waste Conference, 17th, Niagara Falls, Ontario, pages 109—118 (June 7-10, 1970)

The following variables must be considered in the selection of automatic sampling equipment: (1) accessibility of sampling site; (2) general character of the wastes; (3) flow patterns; and (4) analyses to types of samples, namely: (1) individual or 'grab'; (2) simple composite; (3) sequential composite; (4) continuous; (5) hand proportioned composite; and (6) automatic proportioned composite. Sampling equipment ranges in price from a few dollars to several thousand dollars, and in size from the portable to the permanent models. A brief description of the various samplers includes vacuum or compression samplers fixed volume and scoop samplers, cup or bucket elevator samplers, and pump samplers. The important service provided by a sampling schedule must include production of a sample of adequate size, provision for preservation, and provision for containment until analyses can be performed. Growing concern with environmental pollution has caused much interest in monitoring pollutional parameters, but without a representative sample, all analyses performed are merely wasted. Therefore, specification, installation, and operation of automatic sampling devices must be considered a critical part of any waste survey.

Keywords: automatic control, analytical techniques, analysis, monitoring, dissolved oxygen, temperature, flowmeters, pumps, weirs, water pollution control, hydrogen ion concentration, pump sampler, scoop sampler, and vacuum sampler.

COMPARISON OF WASTE WATER SAMPLING TECHNIQUES

Southwest Research Inst., San Antonio, Texas
D. S. Tarazi, L. L. Hiser, R. E. Childers, and C. A. Boldt
Journal of Water Pollution Control Federation, Vol. 42, No. 5, Part 1, pages 708—732 (May 1970)

A significant difference exists between the data obtained by grab sampling and by flow-weighted composite sampling. The significance of these differences was mainly dependent on the following factors: (1) the overall time period for which the waste water is to characterize, i.e., whether daily or other time increments of pollution loading are to be determined, (2) the confidence levels desired, (3) the variability of both quality and quantity in the specific waste water stream, and (4) whether concentration levels or material transport rates are desired. A comparison is made between grab samples and weighted composites for several industries on the Houston ship channel. From past experience that the number of grab samples required to be equivalent even with 90% confidence limits to a flow-weighted composite is excessive for most of the waste water entering the ship channel. Two waste water streams were utilized in this demonstration. Daily composite and grab samples were taken from both flows. Analyses determined on the first included pH, total residue, filtered COD, TOD, total filtered carbon, and inorganic filtered carbon. The second stream included only total, filterable and non-filterable residues. The 'J' test is used to statistically analyze the collected data and develop confidence limits.

SAMPLING SYSTEM

Keywords: sampling, statistics, monitoring, waste water treatment, automation, analytical techniques, statistical method, probability, evaluation, sampling techniques, 'T' tests, grab samples, and waste water characteristics.

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ASCE, Sanitary Engineering Division Journal

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Chemical Abstracts

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Chemical Engineering Progress

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Dissertation Abstracts

Environmental Protection Technology Series

Environmental Research

Environmental Science and Technology

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ISA Journal

Pollution Abstracts

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Public Works

Water and Sewage Works

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Water Pollution Abstracts

Water Pollution Control Federation Journal

Water Pollution Control Research Series

Water Research

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